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AERODYNAMIC ANALYSIS OF A
U.S. NAVY AND MARINE CORPS
UNMANNED AIR VEHICLE

by

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AERODYNAMIC ANALYSIS OF A U.S. NAVY AND MARINE CORPS UNMANNED AIR VEHICLE

by

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the degree of

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ABSTRACT

An aerodynamic analysis was performed on a U.S. Navy and Marine Corps Unmanned Air Vehicle (UAV) called PIONEER. A low-order panel method called PMARC (Panel Method Ames Research Center) was used to obtain various aerodynamic parameters and to evaluate the longitudinal and directional stability and control of the vehicle. In addition, a drag analysis of the vehicle was performed using techniques described in Fluid Dynamic Drag by Hoerner. Drag reduction methods were also investigated. The neutral point of the large tail PIONEER was calculated to be at 74% of the mean aerodynamic chord (MAC). The small tail neutral point was calculated to be at the 51%MAC position. Cross wind limitations were obtained for PIONEER. The maximum sideslip angles due to cross wind were determined to be 8.5° and 18°. For an approach speed of 65 knots, cross wind limits were calculated to be ten knots and 22 knots for the single rudder and dual rudder cases, respectively. Drag polars were plotted for PIONEER. It was determined that drag on the vehicle could be reduced by 29% using simple and cost effective modifications to the vehicle. Follow-on analysis of PIONEER through the Naval Postgraduate School UAV Flight Test Research Program and through full-scale wind tunnel testing at the National Full-Scale Aerodynamics Complex were also discussed.

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I. INTRODUCTION

Unmanned Air Vehicles (UAV's) have become an integral part of modern warfare. From Viet Nam to the Bekaa Valley in Lebanon, UAV's have been used to extend the eyes of the battlefield commander. The small size of UAV's, allows them to venture behind enemy lines virtually undetected to perform missions such as gun fire spotting, real time visual identification of prospective targets, bomb damage assessment, and even laser designation of targets. The ability to obtain timely intelligence has been a crucial factor in the success of some military operations, as will be pointed out later.

United States efforts in UAV development have been lacking since the Viet Nam War where approximately 3500 missions were flown by preprogrammed drones, the Teledyne Ryan AQM/BQM-34 [Ref. 1: p. 26]. In 1973, the Defense Advanced Research Projects Agency (DARPA) sponsored the development of an actively-controlled vehicle called PRAEIRE. Although the mission capabilities of PRAEIRE were outstanding, it lacked the range necessary to be a useful battlefield tool [Ref. 1: p. 27]. The next UAV to follow PRAEIRE was a promising vehicle built by Lockheed, the AQUILA.

The United States Army developed AQUILA over a 14-year period. This extensive development included full-scale wind-tunnel testing at NASA Langley. Over one billion dollars were spent on the AQUILA program, making AQUILA a well engineered UAV. Despite all of the effort in its development, AQUILA never made it to operational use by the Army due to the cancellation of the AQUILA program due to a history of management problems. Currently, there are no major United States UAV's being operated by U.S. Armed Forces.

In juxtaposition to the AQUILA program is the United States Navy Short Range UAV program which is currently based on a vehicle built in Israel, the PIONEER. The contrast between these two vehicles lies in their development and management. PIONEER, as will be discussed later, has undergone a short development period, yet, it is operational in U.S. Navy and U.S. Marine Corps units today. This short period of development has been at the expense of extensive analysis and engineering, which has resulted in performance deficiencies of PIONEER. The lack of aerodynamic data on PIONEER and the identified problems of the vehicle form the purpose for this study.

This study will consist of an aerodynamic analysis of PIONEER utilizing an advanced low-order panel method called PMARC as well as an evaluation of the viscous forces acting on the vehicle, using the techniques described in Fluid Dynamic Drag by Hoerner. In addition, analysis of PIONEER through the Naval Postgraduate School UAV Flight Test Research Program and through full-scale wind tunnel testing under the Navy-NASA Joint Institute of Aeronautics will be discussed. The overall purpose of this study is to provide the lead field activity for test and evaluation of PIONEER, The Pacific Missile Test Center (PMTC), with the analytical tools available at the Naval Postgraduate School to aid them in their ability to evaluate current and future UAV's.

II. SHORT RANGE UNMANNED AIR VEHICLE BACKGROUND

The importance and necessity of UAV's are readily apparent by studying two separate military operations which took place in the country of Lebanon. The 1982 Israeli attacks in the Bekaa Valley had a vastly different outcome from the 1983 United States attacks in the same area. One of the key factors in the Israeli success was their extensive use of UAV's. The noted lack of UAV capabilities prompted the U.S. Navy and Marine Corps to quickly acquire a short range system, the Israeli PIONEER.

The desire to expedite the fleet delivery of PIONEER necessitated a concurrent acquisition program, where the vehicle was delivered to the fleet at the same time that it was delivered to the Pacific Missile Test Center for developmental testing. This "Quick-Go" program has had the advantage of getting a system to operational use in record time at the expense of an adequate development program. Despite the successful fleet use of PIONEER, there are performance deficiencies of the vehicle which need to be addressed.

A. LEBANON EXPERIENCE

1. Israeli Bekaa Valley Operations

On 9 June 1982, Israeli armed forces started their advance towards the Bekaa Valley located in southern Lebanon. They faced a Syrian force of 600 tanks whose position was protected by 20 batteries of Surface to Air Missiles (SAM-2's, SAM-3's, and SAM-6's). By 11 June 1982, 19 of the SAM batteries had been destroyed and the armor battle went to the Israelis who had successfully put all of the

Syrian tanks out of action. Much of the success of the Israeli operation can be attributed to the integrated use of UAV's. The Israeli vehicles MASTIFF and SCOUT relayed video pictures of targets as well as electronic SAM radar footprints back to an airborne command post. In some cases, the UAV's served as decoys of Israeli attack aircraft and were used to laser designate enemy targets. Overall, the Israeli operation in the Bekaa Valley was successfully conducted with minimal Israeli losses. [Ref. 2:pp. 266-271,277]

2. U.S. Naval Airstrikes

On 4 December 1983, aircraft from the aircraft carriers Kennedy and Independence launched to attack Syrian positions in retaliation for earlier attacks on U.S. reconnaissance aircraft. The success of the mission was questionable with two aircraft shot down, one pilot killed, one crewman captured, and several civilians on the ground killed from one of the lost aircraft.

One of the noted differences in the Israeli and United States tactics was the Israeli use of UAV's. The use of UAV's decreased friendly losses and increased overall mission success. The December 1983 United States airstrike marked the beginning of the U.S. Navy's acquisition of a short range UAV.

B. PIONEER ACQUISITION

As a result of the loss of U.S. Navy aircraft over Lebanon, Secretary of the Navy John Lehman "was convinced that remotely piloted vehicles or RPV's (UAV's) could identify targets on the ground, and spare pilots from danger." [Ref. 3: p. 1A] After spending a week in Israel observing UAV operations, Lehman directed in a 8 July 1985 Decision Memorandum that a short range UAV be procured using existing technology and off the shelf equipment [Ref. 4: p. II-1].

Lehman's goal was that a UAV contract be signed before the end of the calendar year [Ref. 3: p. 1A].

On 9 August 1985, the Naval Air Systems Command promulgated the System Performance Specification for a Short Range UAV System. The deadline for bids was 30 September 1985, while the fly off date for those competing for the contract was scheduled for November 1985. There were three companies bidding for the contract: Mazlat (the Israeli team of Israeli Aircraft Industries (IAI) and Tadiran), Developmental Sciences Inc., and Pacific Aerosystems. Both U.S. companies asked for a two to three week extension on the fly off date. The extension was denied based on the U.S. Navy's need to get the system to the fleet as soon as possible. This left only the Israeli company in the competition.

PIONEER is a "major modification" to Israeli Aircraft Industries (IAI) SCOUT UAV. It is built by a team of two Israeli companies, IAI and Tadiran. On 29 December 1985, the U.S. Navy awarded the short range UAV contract to Mazlat-AAI. AAI is the U.S. company through which the PIONEER is sold to the U.S. Government. The U.S. Navy was PIONEER's first buyer. After the initial contract of $25.8 million was awarded, the U.S. Navy ordered additional equipment which brought the contract total up to $100 million for a total of 72 vehicles and associated support equipment. [Ref. 3: p. 1A]

Since the 8 July 1985 SECNAV UAV Decision Memorandum, the PIONEER program has differed from the norm in terms of its Request for Proposal, its Test and Evaluation Program, and its introduction and integration into Navy and Marine Corps fleet operations. Much of this can be attributed to the priority that the Secretary of the Navy placed on UAV's. Capt P.E. Mullowney, the Naval Air Systems Command UAV Program Manager since June 1985, stressed that "the

Navy was seeking a proven design that could be bought 'off the shelf' and placed quickly in service...."[Ref. 3: p. 1A] In order to expedite an initial fleet UAV operational capability, a concurrent program was necessary. A concurrent program requires concurrent developmental testing and operational testing/fleet operations. At the same time that the PIONEER UAV System was turned over to the Pacific Missile Test Center (PMTC) for test and evaluation, the system was sent to newly formed Navy and Marine Corps UAV units. Fleet Composite Squadron Six, stationed at NAS Patuxent River, has been deploying PIONEER on board the USS Iowa, while the First and Second UAV Companies of Marine Corps Base (MCB) 29 Palms and MCB Camp LeJeuene respectively, have been supporting Marine Amphibious Units deploying aboard amphibious assault ships (LHAs). While the various UAV units are trying to integrate the PIONEER System into fleet operations, PMTC is conducting Developmental Testing of PIONEER to determine its suitability to performing the Navy's short range UAV mission. This "concurrent program" has advantages and disadvantages, which will be discussed in the following section.

C. PIONEER DEVELOPMENTAL/OPERATIONAL TESTING EXPERIENCE

PIONEER is a major modification of a proven Israeli design, as it is a larger scale version of the SCOUT. Successful performance of a UAV in a military operation does not guarantee the same performance when operated by a different military in a different scenario. The aerodynamic requirements on the UAV's operated by the Israeli Defense Forces is by nature of the area of UAV operations, less demanding than the requirements of United States UAV's. The Israeli Forces operate in an area limited by size against the same threat. In contrast, United States

military forces operate in a multitude of operational areas and scenarios with the largest differences of UAV requirements being the need for shipboard capability and longer range. In the case of PIONEER, the expanded requirements placed on the Israeli UAV have brought to question how adequate is an already "proven" UAV when operated by the United States military. Operational and developmental testing have pointed out that PIONEER is not without performance and control difficulties. Reliance on an already proven design, or in this case, an already proven design for a similarly configured vehicle, has left PIONEER in need of further analysis and aerodynamic improvements.

1. Fleet Operations

The concept of shipboard UAV operations was tested as part of "Quick-Go, phase one" program, which was the plan to accelerate the introduction to the fleet of a short range UAV. The Israeli UAV MASTIFF was flown from the amphibious assault ship USS Tarawa between June 1986 and November 1986. In December 1986, PIONEER was successfully operated from the battleship USS Iowa. In January and February 1987, PIONEER was deployed on the Iowa for an operation which utilized PIONEER. The concept of integrated UAV operations was proven .[Ref. 4: P. III-1] PIONEER has continued operations on USS Iowa as well as on the battleship USS New Jersey.

Although the early shipboard trials of PIONEER were successful operationally, four vehicles were lost. These losses were attributed to shipboard recovery techniques and possible electromagnetic interference problems [Ref. 5: p. 31]. Possible contributing factors to the recovery techniques were the lack of knowledge about PIONEER's low-speed flight characteristics, possible longitudinal and directional controllability problems at low airspeeds, and the turbulence associated

with shipboard operations. Consequently, these factors have resulted in a relatively fast and flat approach which usually results in minor damage to the vehicle such as broken propellers, antennas, etc., during net recoveries[1]. Exploring the slow speed characteristics of PIONEER would possibly enable slower approach speeds which would reduce damage to the vehicle and reduce mission turn-around time.

2. Flight Test

The Pacific Missile Test Center (PMTC) at Point Mugu NAS is the lead field activity for flight test and evaluation of PIONEER. The responsibility of the UAV Program Office at PMTC is to plan, conduct, test and coordinate the developmental testing of PIONEER. The guidance for developmental testing comes from the Test and Evaluation Master Plan No. 1217, Short Range Unmanned Air Vehicle (PIONEER). The main objectives of the testing program are to determine the overall system capabilities and limitations of PIONEER and to evaluate modifications to the vehicle. [Ref.4: p. III-4]

The major changes to the original vehicle design consist of using a new 65-horsepower Teledyne rotary engine and increasing the size of the horizontal tail. The new engine is similar in size and power to an engine which is being developed to use JP fuel. The current engine, a Sachs 26-horsepower two-stroke engine, uses 100-octane aviation fuel which is more volatile than JP fuel and requires special handling and storage on board naval vessels. The purpose of the enlarged tail is to increase static longitudinal stability and controllability. Some of the improvements to the vehicle have brought with them additional problems. The restrictive acceptable

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[1] Phone Conversation, 11 May 1989 between author and Major Donohue USMC, PMTC, UAV Program Office, Code 1098, Pt.Mugu NAS, CA

cg position of PIONEER of 31.0% Mean Aerodynamic Chord (MAC) to 37.0% MAC[2] is affected by the increased engine and tail size. The subsequent rearward weight shift of the vehicle's center of gravity (cg) position , requires that lead weights be strapped to the front of the vehicle in order to move the cg back to an "acceptable" position. A study into expanding the allowable center of gravity position of PIONEER could possibly result in greater flexibility in payload configurations as well as a reduction in overall drag from the elimination of any external ballast.

3. Vehicle Performance

Flight testing of actual vehicle performance has taken place at PMTC while engine tests have been performed at the Naval Air Propulsion Center, Trenton, NJ. In some cases the performance predicted by the manufacturer varied from test results by as much as 80 percent. Two significant discrepancies are the reduced values of range and endurance, which could point to a possible poor drag prediction of the vehicle. One possible explanation for the large differences between the predicted and test values could be that the aircraft performance charts currently available are based on extrapolated data from the SCOUT UAV.[3]

The purpose of the Flying Qualities and Performance (FQ & P) testing program at PMTC is to determine the flight regime of the PIONEER vehicle. Some of the specific areas being investigated are: best angle and rate of climb speed, best endurance altitude/airspeed, minimum controllable airspeed (to be determined by

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[2] Phone Conversation, 5 June 1989 between author and Ltcol Mortensen USMC, PMA-263, Naval Air Systems Command, Washington D.C.

[3] Phone Conversation, 29 August 1988 between author and Ltcol Thomas USMC, PMA-263, Naval Air Systems Command, Washington D.C.

"investigating impending stall characteristics"), and static longitudinal and directional stability and control [Ref. 6: p. i (objective)]. A 25-channel telemetry package as well as an on board nine-track tape recorder are being used to collect the appropriate data. Even with the most accurate of testing, there is some information which will be difficult to obtain while flying a flight test profile by remote control. Specifically, determining the minimum controllable airspeed by "investigating impending stall characteristics" could result in the loss of the vehicle. Testing for the maximum cross wind limit, or the static directional characteristics of the vehicle, could possibly result in damage to the vehicle.

In addition to the inadequate development period of PIONEER caused by the concurrent acquisition program, a systematic method of evaluating UAV performance is lacking. Despite the complexity and cost of modern UAV's, performance evaluation tends to be subjective. In one flight test report conducted by PMTC, the directional controllability of PIONEER was evaluated by the "feel" of the external pilot [Ref. 7: p. 13]. Four ways to enhance the FQ & P testing program and to provide PMTC with a systematic means to evaluate vehicle performance are to: 1) perform an aerodynamic analysis of PIONEER using a low-order panel method called PMARC; 2) do a drag analysis of PIONEER to include means of reducing the overall vehicle drag; 3) conduct flight testing with the half-scale PIONEER through the Naval Postgraduate School UAV Flight Test Program; and 4) conduct a full-scale wind tunnel test of the PIONEER vehicle at the National Full-scale Aerodynamics Complex of the NASA Ames Research Center. This proposed analysis will not only benefit PIONEER, but will serve as the groundwork for studies of future UAV's of similar configuration.

III. AERODYNAMIC ANALYSIS OF PIONEER

A. PMARC/PAD

PMARC (Panel Method Ames Research Center) and PAD (Plot Aerodynamic Data) are FORTRAN codes currently being developed and used by NASA computational fluid dynamics engineers at the Ames Research Center. PMARC is a low-order potential-flow panel code which is used for modeling aerodynamic flow around and through a complex three-dimensional geometry. PMARC is a non-proprietary code which is based upon a low-order panel code, VSAERO. The current configurations of PMARC enable it to run on Cray X-MP, MicroVax II, Macintosh II, and Macintosh Plus computers.

PAD is a non-proprietary plotting package developed by Sterling Federal Systems, Inc. for use with PMARC and VSAERO in a VAX/MicroVAX environment. PAD is an interactive program which converts three-dimensional geometry data to two dimensions and plots the geometry on the VAX terminal screen. The proprietary Tektronix code, TCS, is a necessary and integral part of the PAD plotting routine. PAD allows the plotting of aerodynamic data, boundary layer data, on-body streamline data, and off-body streamline data superimposed over the test geometry. PMARC and PAD were utilized on the Naval Postgraduate School Aeronautical Engineering CAD/CAE Laboratory MicroVax system, the Basic Fluid Mechanics MicroVax system at the NASA Ames Research Center, and the NASA Ames Cray X-MP system in order to accomplish the aerodynamic analysis of PIONEER. In addition, PAD was used on the IRIS work station at the

40x80 foot Wind Tunnel Complex at NASA Ames during the course of the analysis.

1. PMARC Background

PMARC allows a three-dimensional geometry to be modeled by placing a constant distribution of source and doublet singularities on quadrilateral panels of a surface geometry [Ref. 8: p. 3]. This constant distribution is what distinguishes PMARC as a low-order panel method. In a high-order method, the singularities are allowed to vary across the panel. The high-order method generally yields better results than the low-order method, but at the expense of higher computation time and complexity [Ref. 9: pp. 4-5]. A unique modeling capability of the PMARC program is its time stepping wake. The wake shape and direction are reshaped at a time step interval prescribed by the user, which allows the wake to follow a panel geometry in motion. This capability allows aerodynamic modeling of maneuvering aircraft. [Ref. 9: p. 13]

The doublet strength on the surface panels is calculated iteratively to solve for the strength which yields a flow over the outer side of the geometry panels which is tangential to the panel surface. For lifting surfaces, a wake is shed from the trailing edge. As with the panel doublet strength, the wake doublet strength is solved for iteratively so that at the wake starting point, no load is carried. With no load carried at the trailing edge of the wing, the Kutta condition is satisfied. [Ref. 10: p. 10]

Once the final doublet solution is found, the doublets are differentiated numerically to obtain the panel surface velocities. Pressure coefficients are computed at each panel centroid from the surface velocities, allowing a force and moment to be found for each panel. When the pressure influences on each panel are summed

together, the total non-viscous aerodynamic forces and moments acting on the vehicle are obtained. [Ref. 9: p. 15]

The overall forces and moments are nondimensionalized to force and moment coefficients by the reference area and chord which are specified in the initial input deck. These coefficients are transformed to wind, stability, and body axes. The wetted area of the input geometry is nondimensionalized by the reference area and written to the output file along with all of the input geometry, output geometry (panel unit normals and panel corner points), and the aerodynamic data for the panels, patches, components, and assemblies. [Ref. 9: pp. 15-16]

2. Wing Evaluation

The first part of the PIONEER analysis consisted of modeling the wing alone at angles of attack from -4° to 10°. Figure 1 shows a half plane model of an NACA 4415 wing with an aspect ratio of 9.1 and its initial wake.

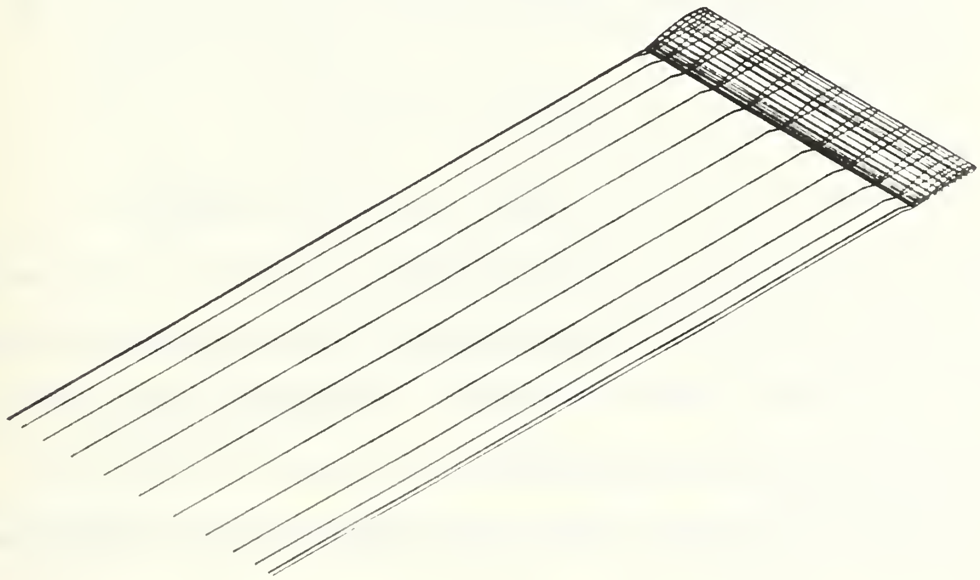


Figure 1. NACA 4415 Wing, AR = 9.1

A half-plane model can be used as long as the airflow and geometry are symmetric around the XZ plane as defined in the VSAERO User's Guide [Ref. 11: p. 8]. PMARC automatically adds the influence of the mirror image when calculating the total force and moment coefficients. Three different aspect ratios were evaluated as part of the initial PMARC runs. Figure 2 shows the effects of aspect ratio on lift. As was expected, the higher aspect ratio wing had the highest lift coefficient due to its increased efficiency.

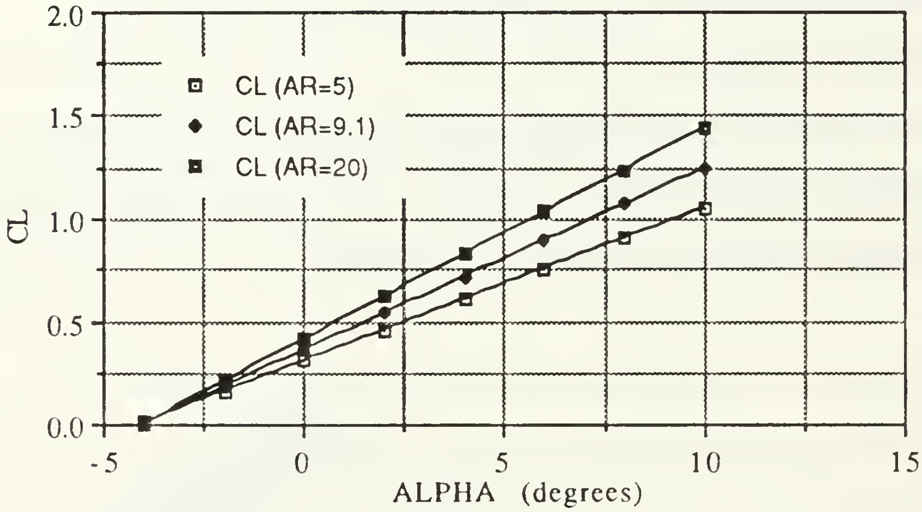


Figure 2. CL vs Alpha (NACA 4415 Wing)

Figure 3 shows the change in inviscid drag with aspect ratio. The reduced downwash effects of the longer wing results in less induced drag. Notice that there is still drag on the wing at the zero lift condition. PMARC models pressure drag on the geometry in addition to the induced drag.

Figure 4 shows the results of aspect ratio on pitching moment versus the angle of attack.

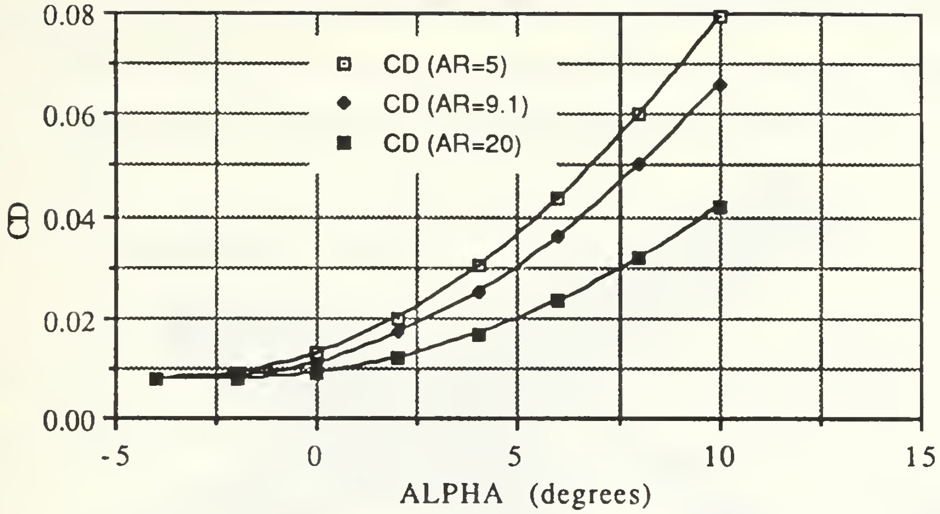


Figure 3. CD vs Alpha (NACA 4415 Wing)

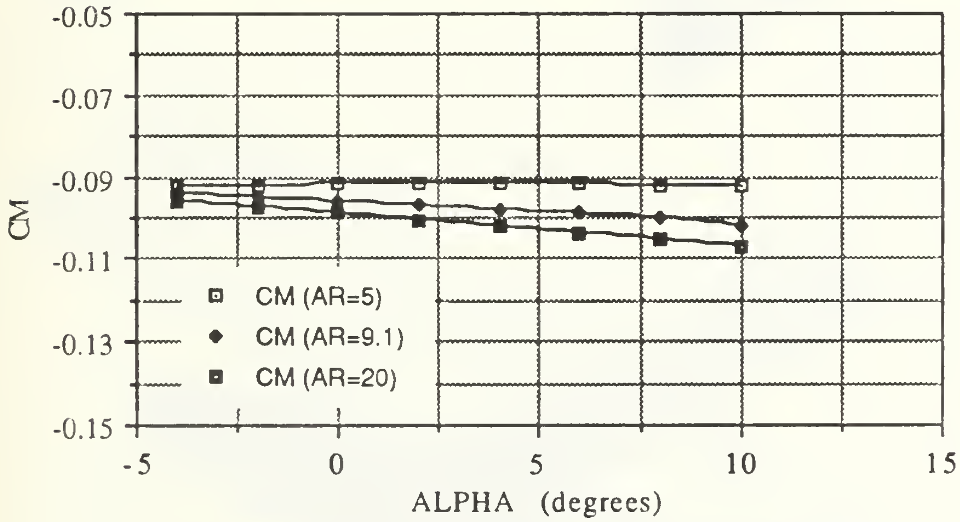


Figure 4. Cm vs Alpha (NACA 4415 Wing)

3. PIONEER Evaluation

Two different configurations were analyzed for the longitudinal stick-fixed case and two different rudder configurations were evaluated for the directional case. Figure 5 shows the plotted geometry for the large tail PIONEER while Figure 6

shows the small tail PIONEER. The larger tail surface is 75% larger than the small tail surface.

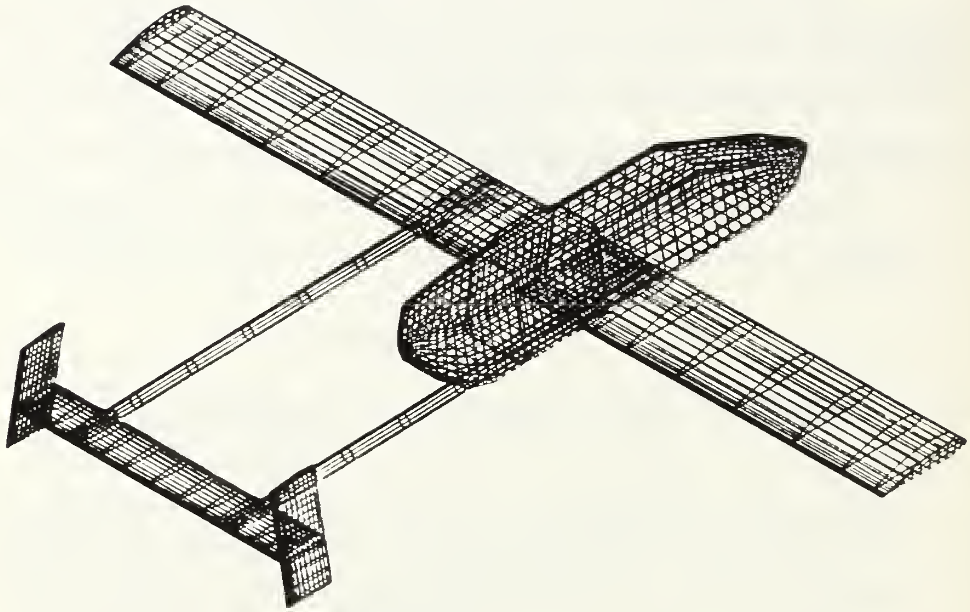


Figure 5. PIONEER (large tail)

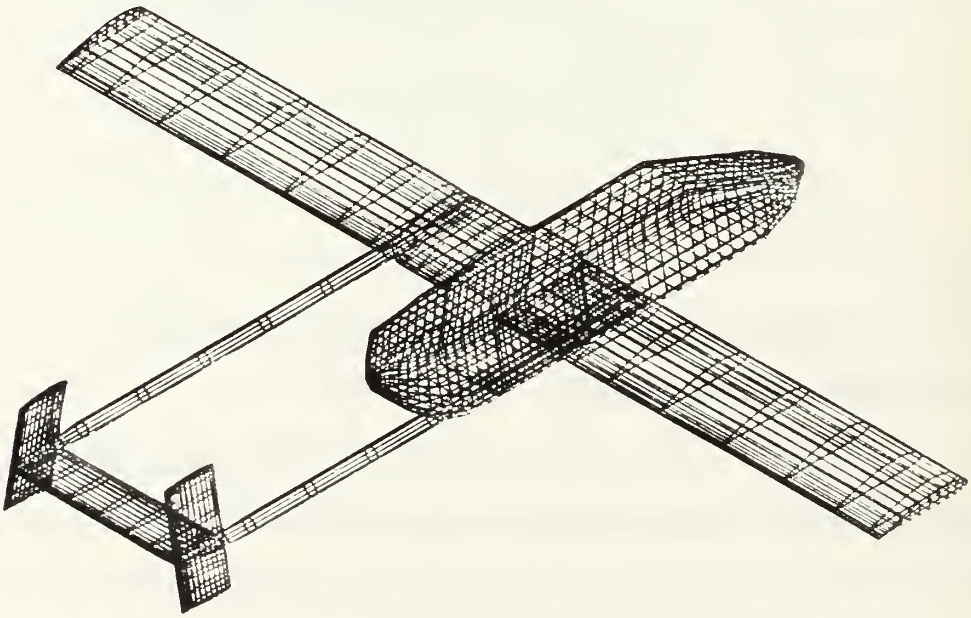


Figure 6. PIONEER (small tail)

The directional case was evaluated for the large tail vehicle only. It is assumed that there is negligible difference from the center of lift for the vertical tail surfaces between the small tail and large tail configurations of PIONEER to the center of gravity location.

a. Longitudinal Stability and Control

Due to symmetry, only the half-plane was evaluated for the longitudinal case. The initial analysis consisted of running PMARC with the individual components of the PIONEER vehicle for a cg location of 33%MAC: the wing (Figure 7), the fuselage (Figure 8), and both tail surfaces, the large tail (Figure 9), and the small tail (Figure 10), for angles of attack from -4° to 10°.

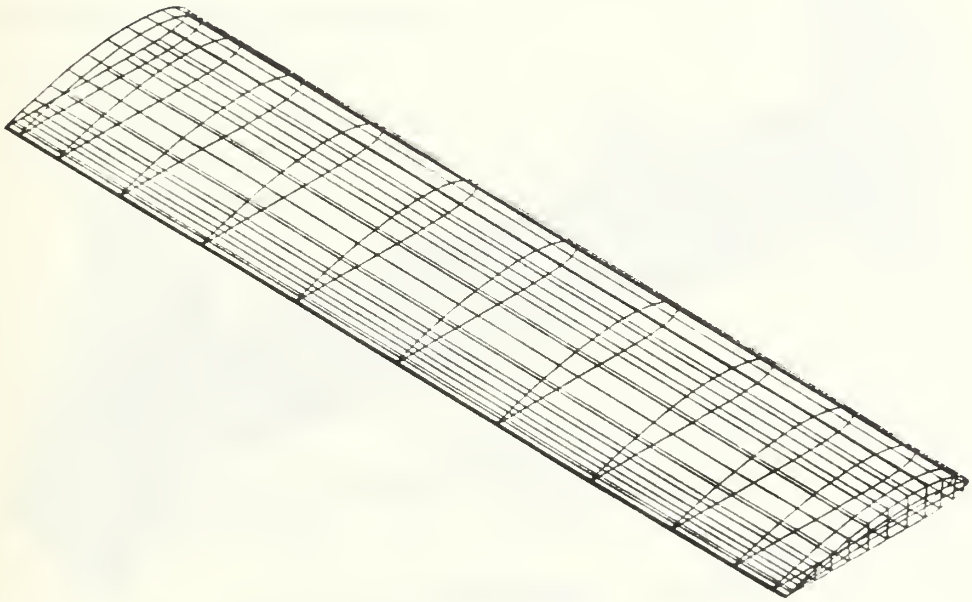


Figure 7. PIONEER Wing

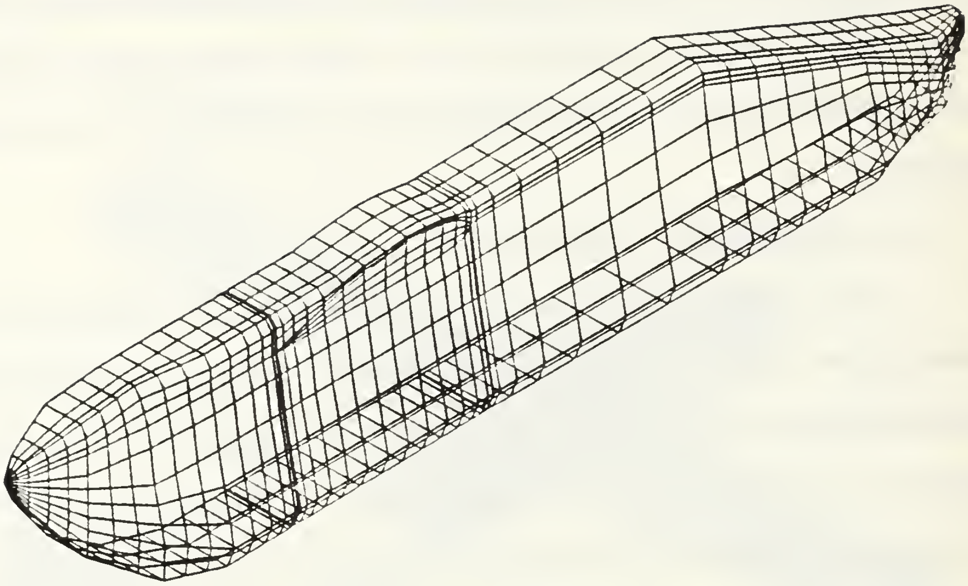


Figure 8. PIONEER Fuselage

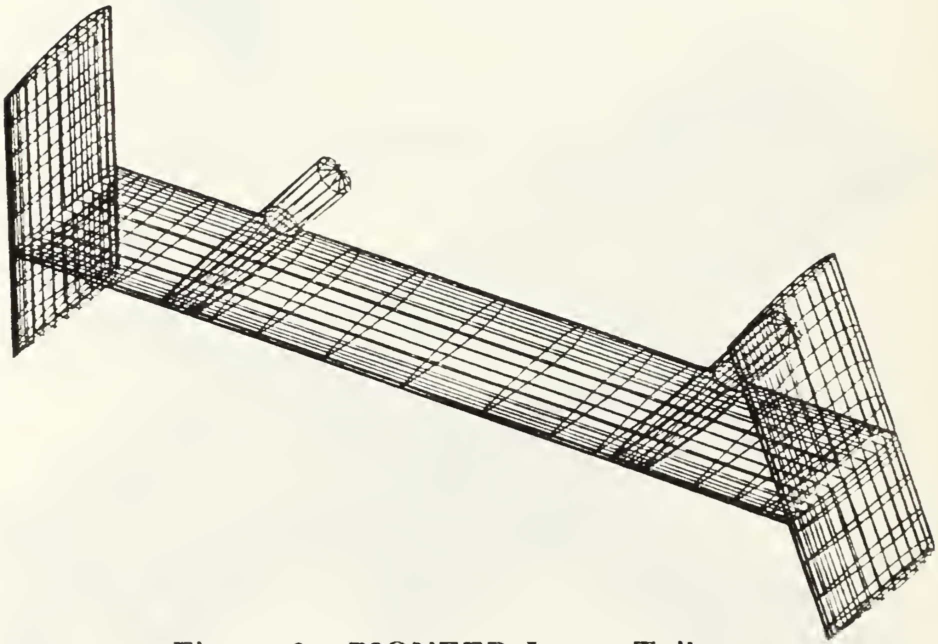


Figure 9. PIONEER Large Tail

Even though Figure 9 shows the full view plane, only the half-plane was modelled. The PAD program gives the option to mirror the paneled geometry to the unpaneled side of the geometry as shown in this figure.

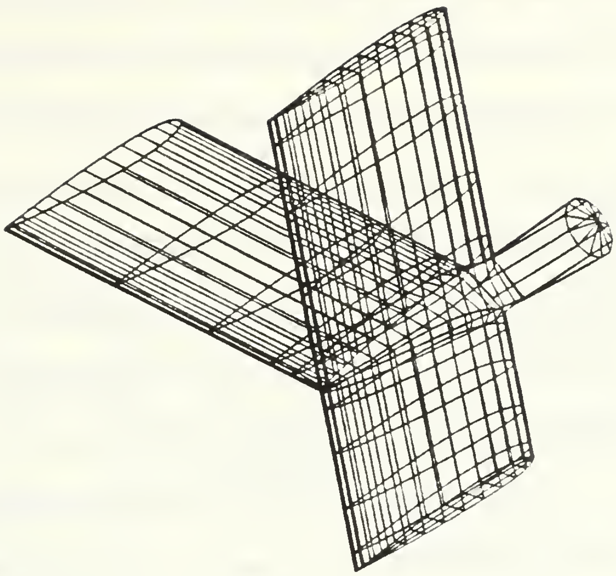


Figure 10. PIONEER Small Tail

The results from the component runs were combined to obtain the net forces and moments on the vehicle (Figures 11).

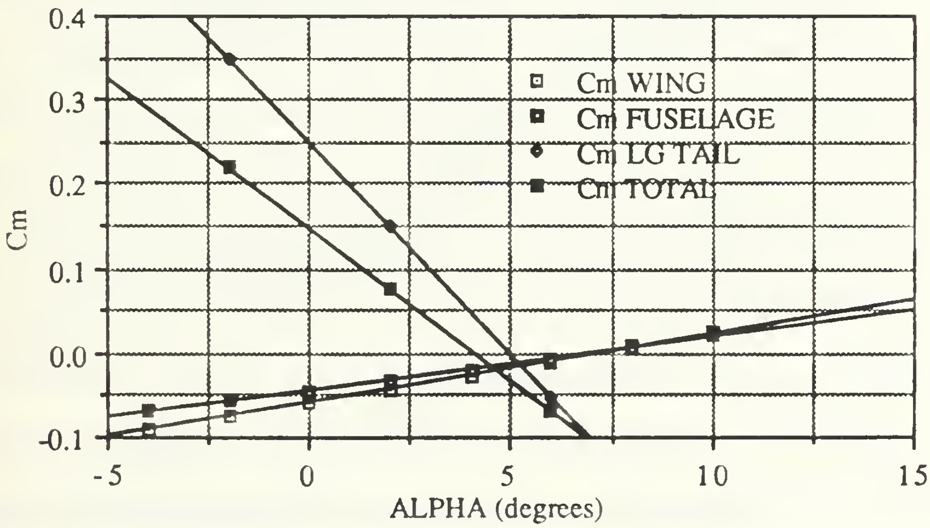


Figure 11. PIONEER (large tail) - Cm vs Alpha

The destabilizing effects of the fuselage and wing can be seen. The stabilizing tail, when combined with the destabilizing wing and fuselage, gives the vehicle a positive

zero lift pitching moment and a negative slope of pitching moment versus angle of attack, both of which are needed to have trimmed positive longitudinal static stability.

The entire half-plane vehicle was then run and the results were compared to the initial component runs. Figure 12 shows a comparison for the large tail configuration. The results of the complete vehicle run for the large tail are in accordance with what one would expect when the downwash from the main wing impinges upon the horizontal tail. The lower and higher angle of attack pitching moments shift towards zero pitching moment, showing that the tail is less effective because of the reduced effective angle of attack. Although some of these results seem trivial, each result that is in accordance with expectations, increases the confidence in the technique being used.

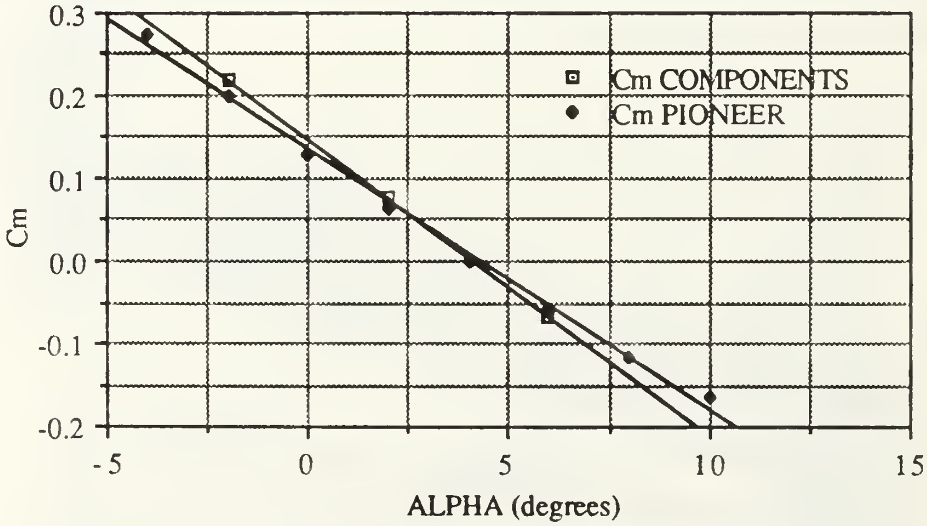


Figure 12. PIONEER (large tail) - Cm vs Alpha

Not all of the PMARC runs had reassuring results as the small tail complete vehicle run discussed below shows.

The individual components were analyzed for the small tail case in the same manner as for the large tail case (Figure 13). The results were as expected, with the longitudinal pitch stability being less than than the large tail case.

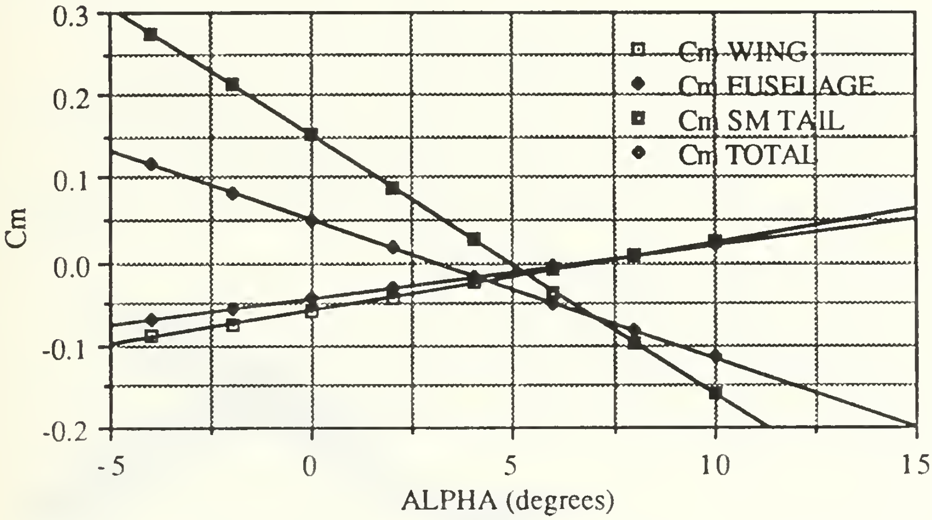


Figure 13. PIONEER (small tail) - Cm vs Alpha

Next, the complete half-plane vehicle was run for the small tail configuration (Figure 14). A comparison of the small tail component run to the small tail complete half-plane run were reasonable for the lower angles of attack, but were not in accordance with expected results for higher angles of attack as shown in Figure 15. The downwash produced by the main wing increases with lift, which reduces the effectiveness of the horizontal tail. Figure 15 shows the opposite effect where the tail is more effective in the presence of higher downwash. Suspect results were also obtained for the small tail lift (Figure 16).

The lower angle of attack small tail vehicle lift is higher for the stick fixed or untrimmed case than the for large tail case. This is a reasonable result as the smaller tail would produce less negative lift than the larger tail at the same low angle of attack, giving the overall vehicle lift a higher value. At the higher angles of attack however,

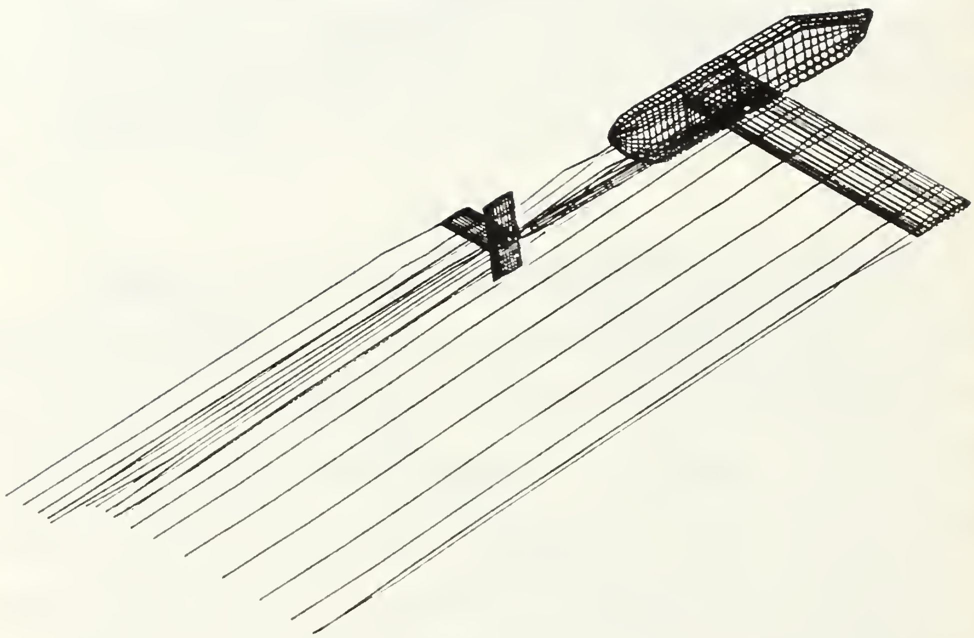


Figure 14. PIONEER (small tail) - PMARC, AOA = 2°

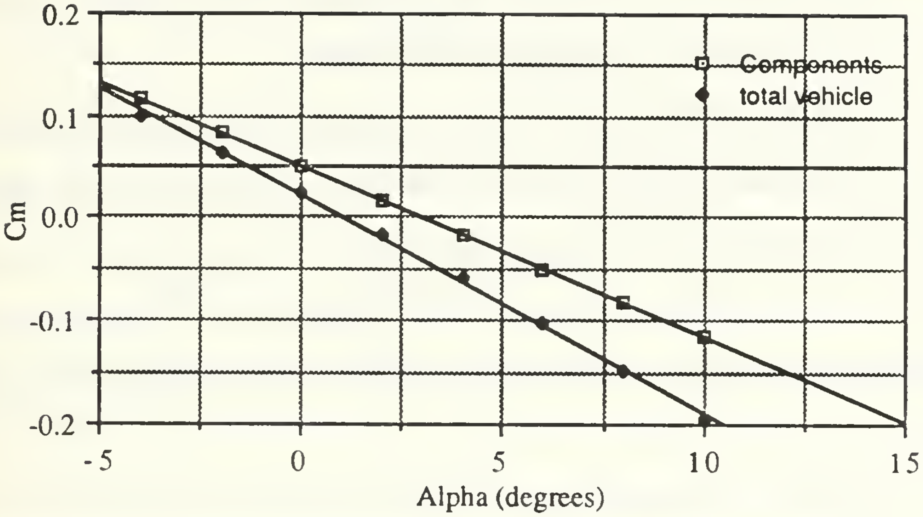


Figure 15. PIONEER (small tail) - Cm vs Alpha

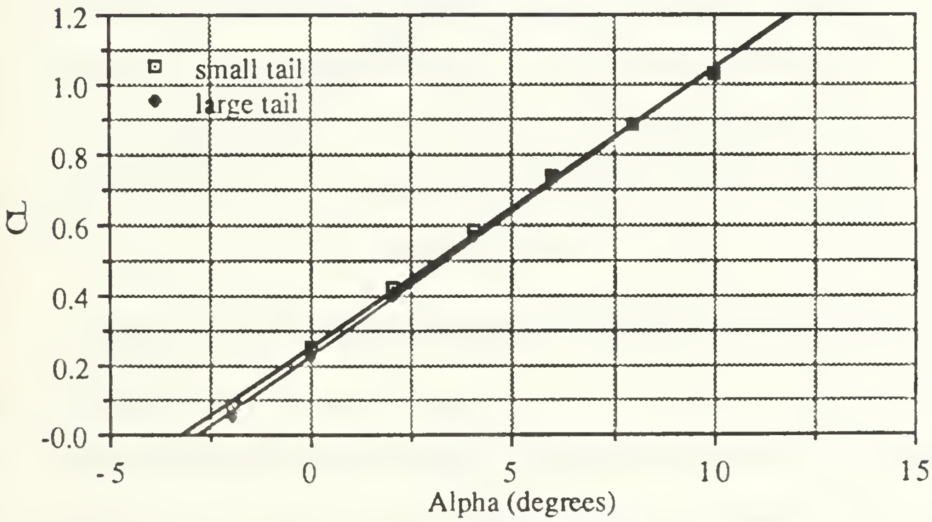


Figure 16. PIONEER (small tail) - CL vs Alpha

the small tail lift would be expected to be less than the lift for the larger tail. Figure 16 shows that this result was not obtained. The reason that the small tail, higher angle of attack lift and pitching moments did not behave as expected, could not be explained. The results of the complete half plane small tail runs are considered to be invalid and were not used in the analysis of PIONEER.

It was assumed that the relative loss of tail effectiveness due to downwash is similar for the small and large tail cases. The difference between the large tail pitching moment for the complete half-plane vehicle and for the components was used as a correction for the small tail component results (Figure 17). This correction was applied during the analysis of PIONEER to all of the component longitudinal results.

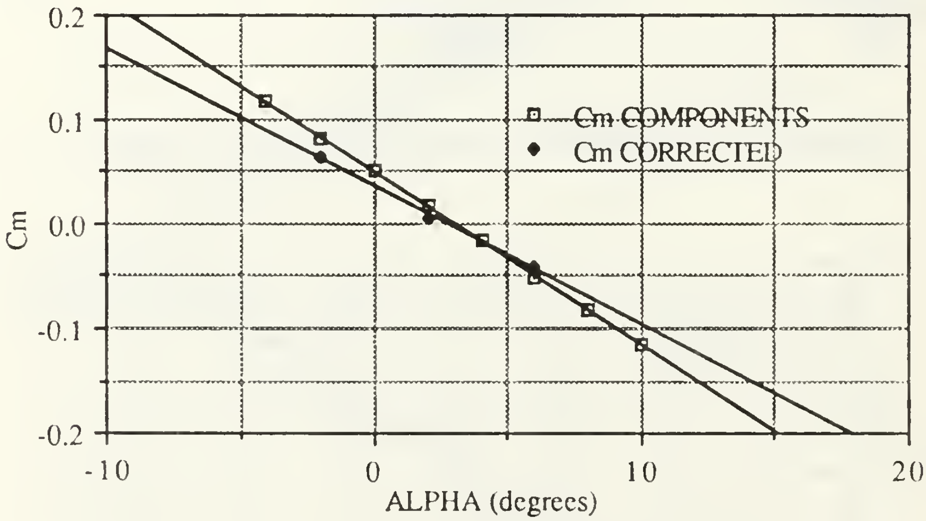


Figure 17. PIONEER (small tail) - Cm vs Alpha

The longitudinal static stability was compared for the small and large tail cases. Figure 18 shows results which are in accordance with expected values, in that the negative slope of pitching moment versus angle of attack is much steeper for the large tail. The larger tail show a substantial increase in stability.

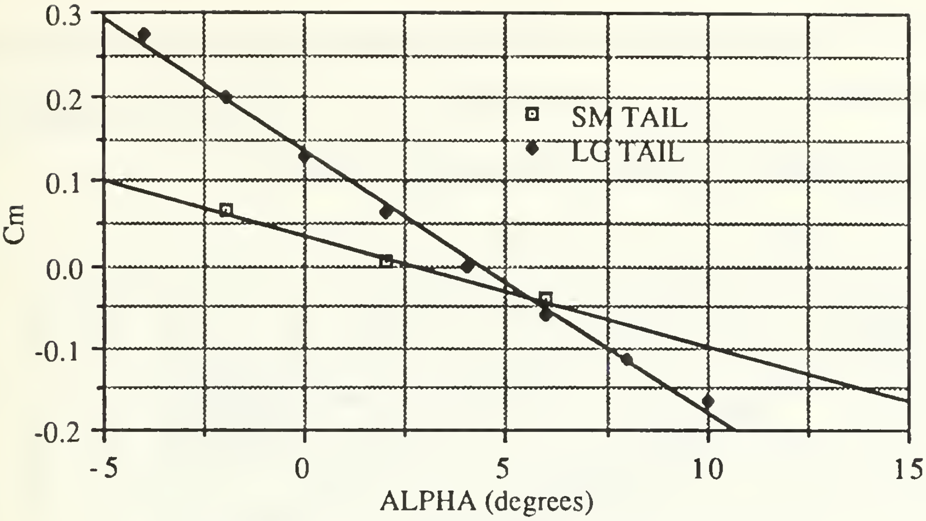


Figure 18. PIONEER - Cm vs Alpha

One of the limitations of PIONEER is the limited range of cg travel as mentioned in the introduction. Part of the PMARC analysis consisted of evaluating different cg locations and finding the neutral point for both configurations. The neutral point is defined as the cg location where the restoring pitching moment change with angle of attack is zero. Runs were made for the vehicle components for three different cg locations. This was accomplished by specifying in the initial input deck, the point on the geometry about which all of the moments are resolved. Figures 19 and 20 show the destabilizing effect that the rearward travel of the cg location has.

The slope of pitching moment versus angle of attack per degrees was converted to per radian and plotted as a function of cg location in terms of the percent of mean aerodynamic chord (MAC) as shown in Figures 21 and 22. For PIONEER, the neutral point was calculated to be at a cg location of 51%MAC for the small tail and 74%MAC for the large tail.

More mission payload flexibility could be obtained if the present cg restriction of 31%MAC to 37%MAC could be expanded. Additionally, the need for external ballast would be eliminated, thus reducing the drag on the vehicle. Table 1 shows a

list of stability and control derivatives for various aircraft types which was obtained from Roskam (Ref. 12: Appendix C). The derivatives for PIONEER obtained from PMARC for a cg location of 33%MAC were added to Table 1.

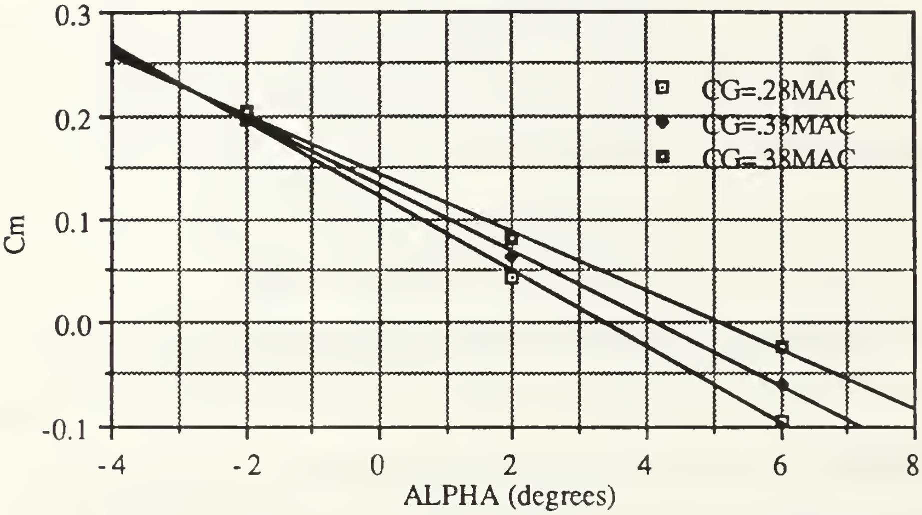


Figure 19. PIONEER (large tail) - Cm vs Alpha

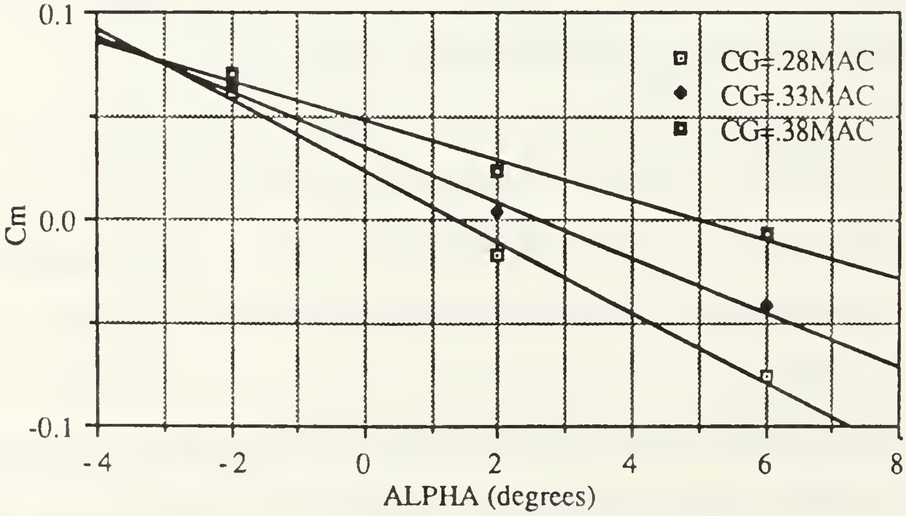


Figure 20. PIONEER (small tail) - Cm vs Alpha

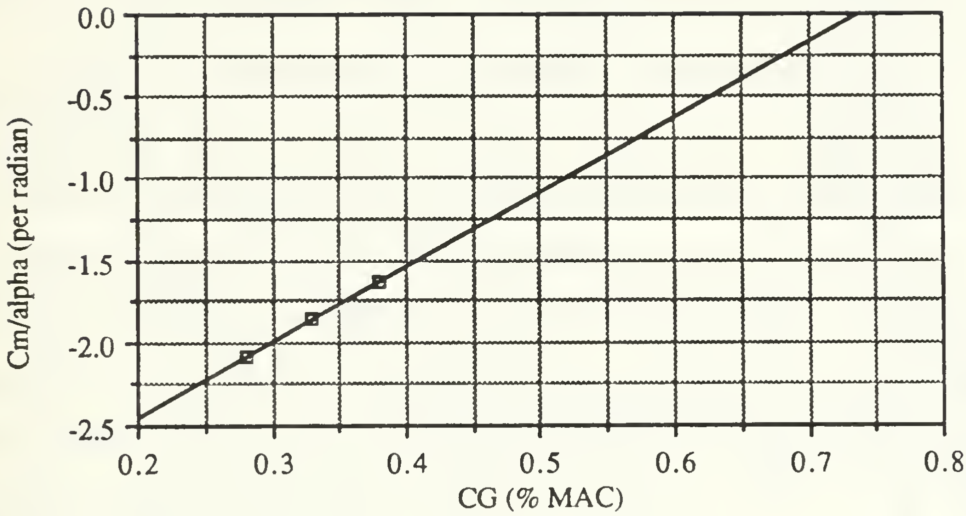


Figure 21. PIONEER (large tail) - Cm/Alpha vs CG Location

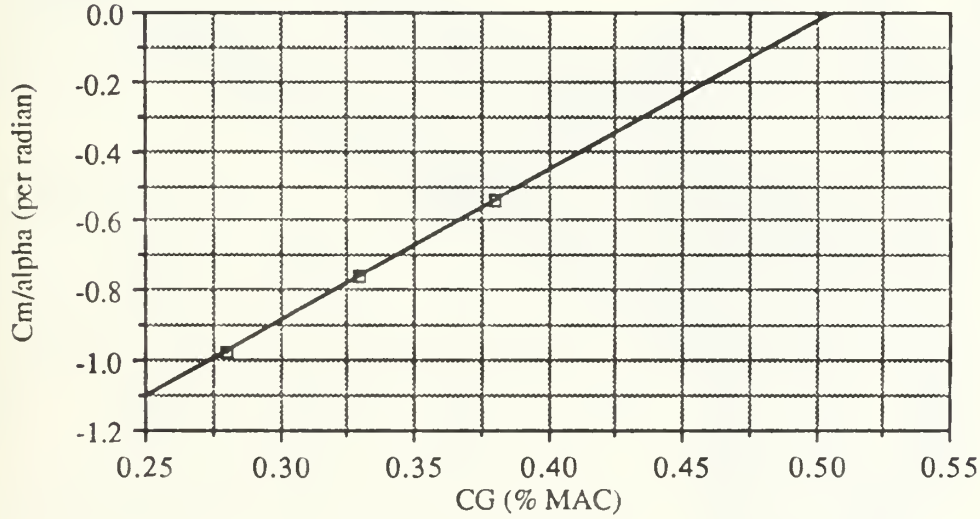


Figure 22. PIONEER (small tail) - Cm/Alpha vs CG Location

TABLE 1. STATIC STABILITY PARAMETERS OF VARIOUS AIRCRAFT (APPROACH CONFIGURATION)

	Cessna 172	Twin Engine	Jet Trainer	Lear Jet	F - 4 Fighter	Boeing 747	Pioneer large tail	Pioneer small tail
(per radian)							[single rudder]	[dual rudders]
C_{m_α}	-.89	-2.08	-.6	-.66	-.098	-1.45	-1.8	-.756
C_{L_α}	4.6	6.24	5.0	5.04	2.8	5.67	4.77	4.6
$C_{L_{\delta e}}$	.43	.58	.39	.4	.24	.36	.407	.264
$C_{D_{\delta e}}$	.06	0.0	0.0	0.0	-.14	0.0	.069	.043
$C_{m_{\delta e}}$	-1.28	-1.9	-.9	-.98	-.322	-1.4	-1.833	-1.18
C_{l_β}	-.089	-.13	-.14	-.173	-.156	-.281	-.565	
$C_{l_{\delta r}}$	.0147	.0087	.03	.014	.0009	0.0	[.063]	[.0796]
Cn_β	.065	.12	.16	.15	.199	.184	.3151	.3151
$Cn_{\delta r}$	-.0657	-.0763	-.11	-.074	-.072	-.113	[-.1203]	[-.2464]
C_{Y_β}	-.31	-.59	-.94	-.73	-.655	-1.08	-.2177	-.2177
$C_{Y_{\delta r}}$	.187	.144	.26	.14	.124	.179	[.1203]	[.2406]

The slope of pitching moment versus angle of attack for PIONEER can be altered to model one of the aircraft types listed in Table 1 by varying the cg location. For example, the static longitudinal stability of PIONEER would be similar to that of a Cessna 172 aircraft with cg locations of 54%MAC for the large tail and 29%MAC for the small tail.

One method to evaluate the accuracy of the PMARC model of PIONEER would be to compare some of the results with flight test or wind tunnel test results. Pursuant to this goal, elevator trim positions were calculated for both tail configurations as a function of lift coefficient. Elevator deflections were modeled for 5°,10°,15°,and 20° of up elevator. Paneled geometries of both tail configurations with deflected elevators are shown in Figures 23 and 24.

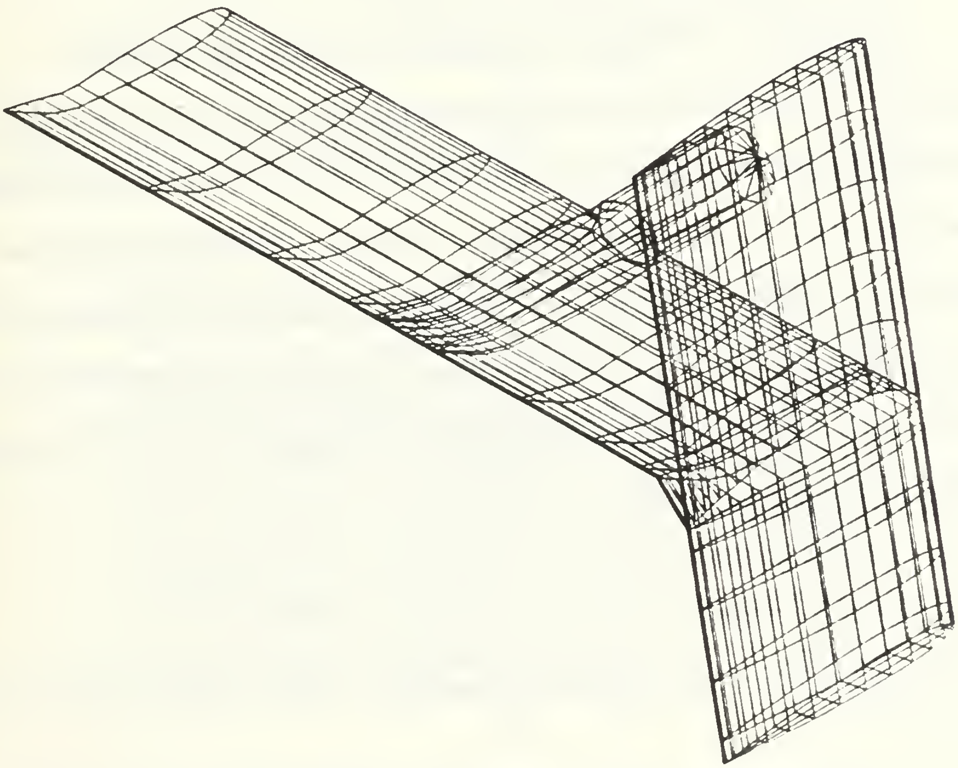


Figure 23. PIONEER Large Tail, 20° Up Elevator

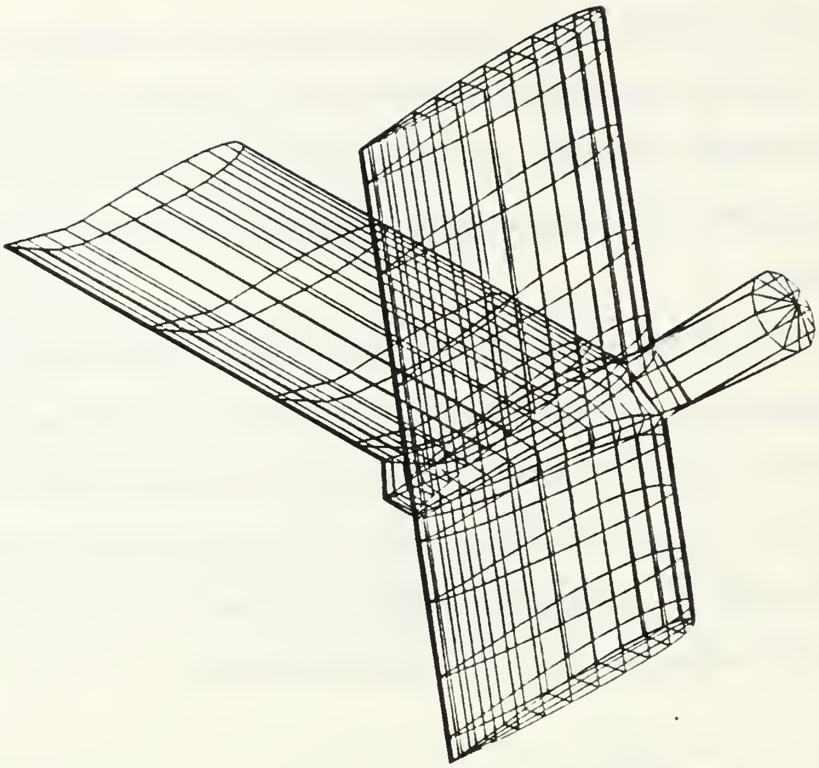


Figure 24. PIONEER Small Tail, 20° Up Elevator

The physical geometry modeled in the above figures differs from the actual physical vehicle at the elevator-vertical tail junction. The PMARC model has panels connecting the deflected elevator to the junction of the vertical tail, whereas with the actual vehicle, a gap would exist. This difference was modeled intentionally since a comparison of experimental results and PMARC predictions at the NASA Ames Research Center shows a better correlation of data for deflected control surfaces when the gap that physically exists is paneled over.[4]

---

[4] Conversation between author and Dale Ashby, NASA Ames Research Center, 2 June 1989.

PMARC runs were made of the small and large tails alone at 2°and 6° angles of attack. The pitching moment coefficients for the tails, wing and fuselage, were combined to obtain a component value of pitching moment about the 33%MAC cg location. The correction from the earlier complete half-plane run was applied to the component values which resulted in the pitching moment coefficient for the entire vehicle at different elevator positions (Figures 25 and 26).

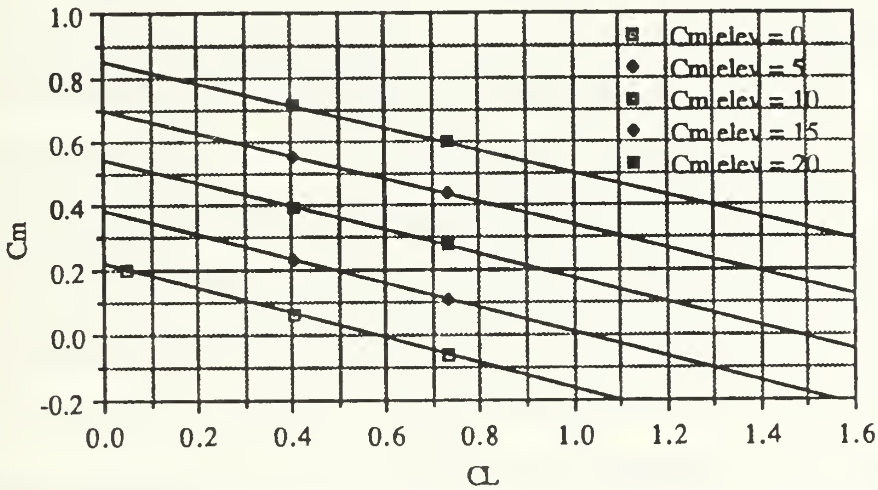


Figure 25. PIONEER (large tail) - Cm vs CL (T.E.U.+)

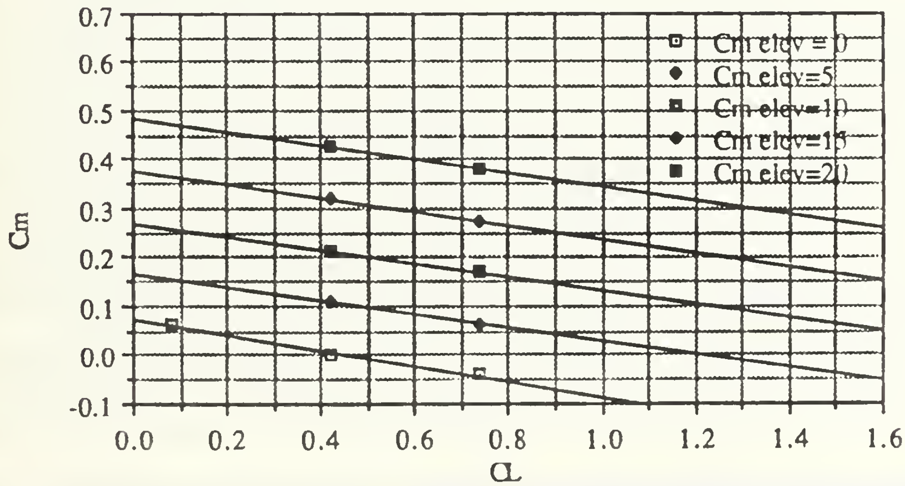


Figure 26. PIONEER (small tail) - Cm vs CL (T.E.U.+)

The elevator trim position for a specified lift coefficient is the position where the overall pitching moment is zero. Three trim positions were taken from Figures 25 and 26 and plotted as a function of lift coefficient (Figures 27 and 28).

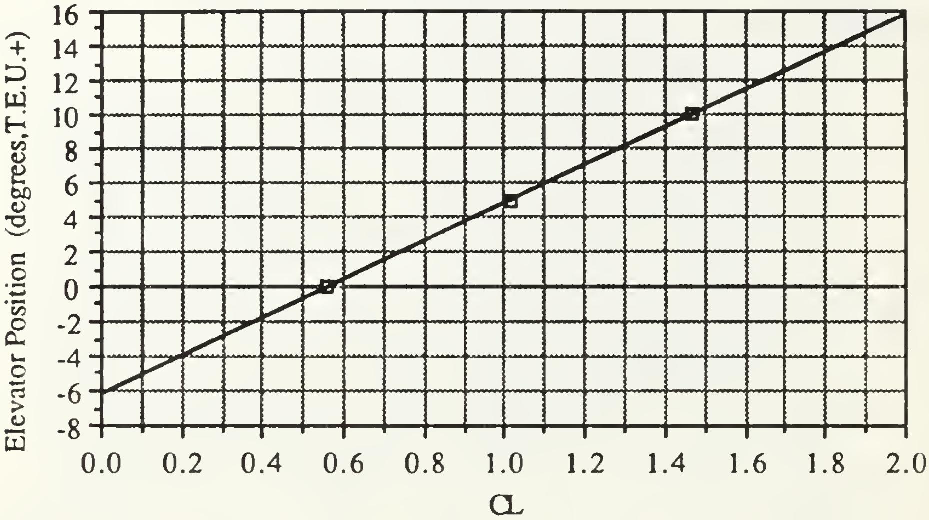


Figure 27. PIONEER (large tail) - Elevator Trim vs CL

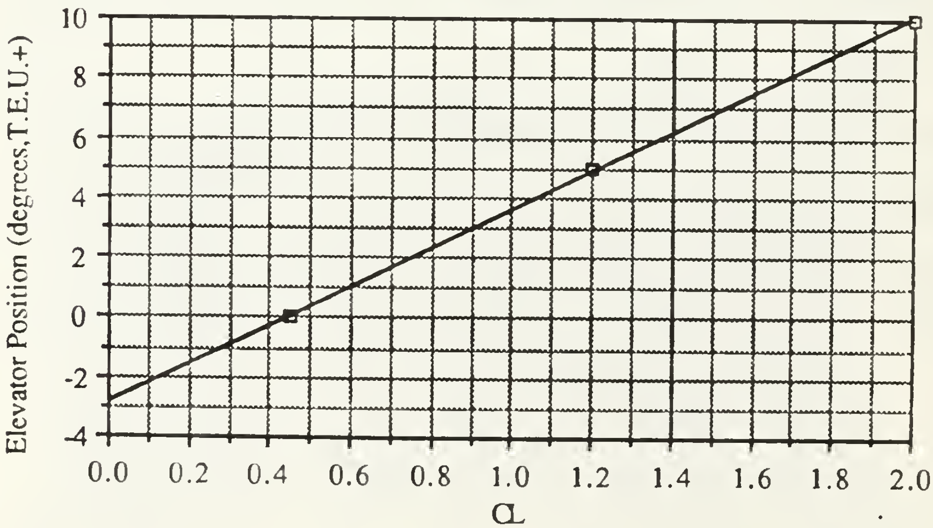


Figure 28. PIONEER (small tail) - Elevator Trim vs CL

Elevator trim position can be obtained during flight testing of PIONEER for a specified lift coefficient and compared to the predicted values in Figures 27 and 28. Correlation between the predicted and actual values would validate this PMARC analysis of PIONEER.

b. Directional Stability and Control

The directional analysis required that both planes of the vehicle be modeled because of the lack of symmetry about the XZ plane. The original analysis plan was to do a component run and look at the combined effects of the components on directional stability and control. These results were to be compared with the results of the complete vehicle. The current paneled geometry, when modeled for both planes, is over 5,000 panels. The upper limit on the compiled PMARC program is 5,000 panels, which would not allow the current geometry to be run. Therefore, the assumption was made that the sidewash due to the fuselage would have a negligible effect on the vertical tail surfaces. The small sidewash which is in reality present, would have the effect of reducing the vertical tail effectiveness, making the restoring yawing moment less than it is in the test case. Thus, the PMARC analysis will be a conservative or "worst case" estimate of PIONEER's cross wind ability. Rather than change the geometry to a coarser grid, the directional stability and control analysis was performed using the combined effects of the components alone with no correction for sidewash.

When the large tail was placed on the actual PIONEER vehicle, the cg shifted rearward due to the increased weight. In an effort to maintain the cg in an "acceptable" location, one of the rudder servos was removed, limiting the vehicle to one rudder. Questions have since arisen concerning PIONEER's cross wind capabilities. Figure 29 depicts PIONEER performing a cross wind landing.

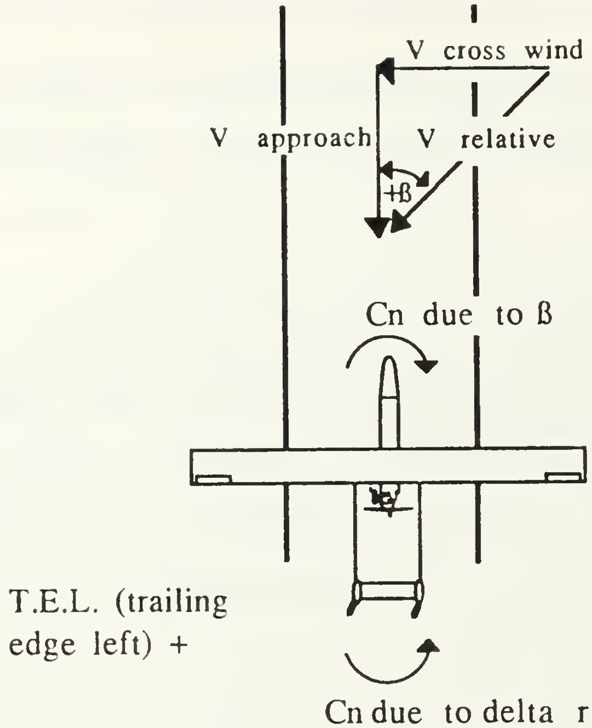


Figure 29. PIONEER - Cross Wind Landing

Cross wind landings require that the vehicle crab "into the wind" during the approach in order to remain lined up with the runway. In this diagram, PIONEER is depicted where it has swung its nose to the left just prior to touch down in order to align itself with the runway. In effect, PIONEER is flying with a sideslip, momentarily before touchdown. Cross wind limitations are really a matter of the ability of the rudder to induce a large enough sideslip to meet the cross wind angle, beta, as depicted in the above diagram. For the case of positive directional static stability, a positive beta (sideslip to the right) will cause the nose of the vehicle to swing to the right , misaligning it from the runway, but aligning the vehicle with the relative wind. In order to prevent the nose from swinging into the displaced relative wind, positive rudder (trailing edge left is positive) is deflected to the degree that a yawing moment is produced which equals in magnitude but is opposite in direction

from the yawing moment due to sideslip. If the rudder authority is sufficient enough, equilibrium can be maintained and the vehicle will remain aligned with the runway. The maximum cross wind limit is defined for a specified approach speed as the speed which produces a sideslip angle where maximum rudder deflection can no longer maintain equilibrium. PMARC was used to obtain the required directional stability and control derivatives so that cross wind limitations could be determined for single rudder and dual rudder configurations of PIONEER.

An approach speed of 65 knots was chosen for the directional analysis. In most cases of approach speeds for PIONEER, the tail would be producing a negative lift for trimmed flight. It was therefore necessary to find the trim elevator position in order to model PIONEER in sideslip accurately. Table 2 shows the numbers that went into determining the elevator trim position for an approach speed of 65 knots.

TABLE 2. PIONEER - ELEVATOR TRIM FOR APPROACH

Weight	Air Density	Wing Area	Approach Speed	Approach Speed	Calculated CL
(pounds)	(slugs/ density)	(ft^2)	(kts)	(ft/sec)	
400	.002368	30.5	65	109.6	.92

An elevator trim position of 4° up elevator was obtained from Figure 27. The geometry was already input for an elevator position of 5° up elevator, so 5° was used as the trim elevator position.

The wing, fuselage and large tail with 5° up elevator (Figure 30) were run at sideslip angles of 5°,10°,15° and 20° with an angle of attack of 7°.

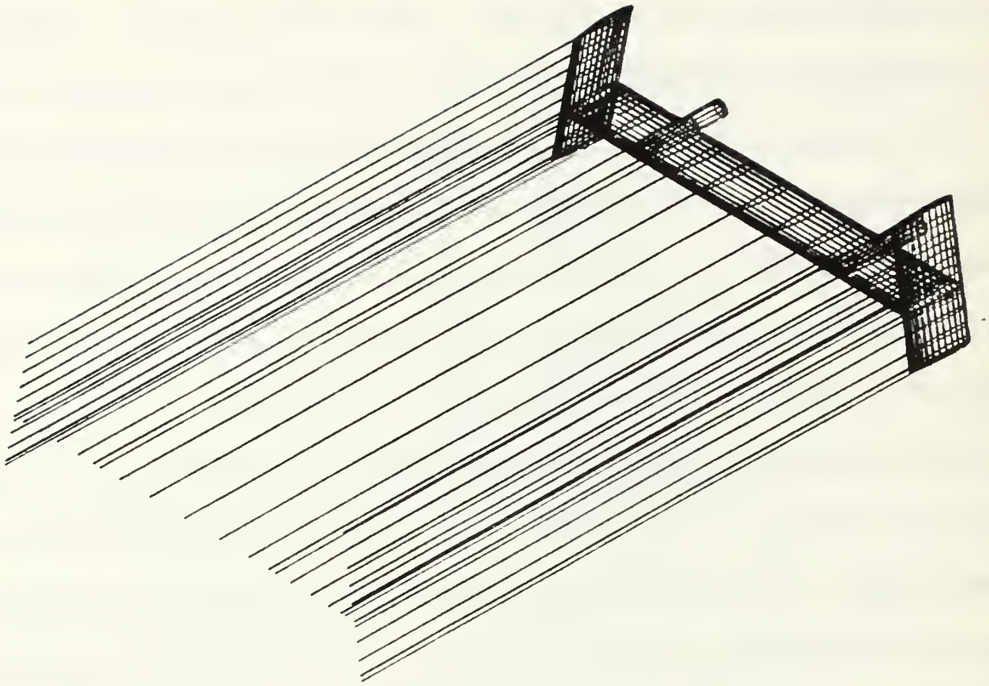


Figure 30. PIONEER Large Tail, 5° Up Elevator

The angle of attack was chosen from Figure 16 where lift coefficient is plotted versus angle of attack. To be more rigorous, the lift curve should be recomputed for the entire vehicle with the trim elevator position in order to run the directional cases at the required angle of attack. This was not done as part of this study in the interest of time. Figure 31 shows the total yawing moment for PIONEER about the 33%MAC cg location as a function of sideslip angle for the rudder fixed case. With the accepted convention of "nose right" yawing moment as positive, Figure 31 shows that PIONEER has positive directional static stability [Ref 13: p.72].

In order to calculate the cross wind limitation for PIONEER, it was necessary to find the amount of yawing moment that the rudders can generate. Two different tail configurations were investigated, one with a single deflecting rudder, and the other with dual deflecting rudders (Figures 32 and 33).

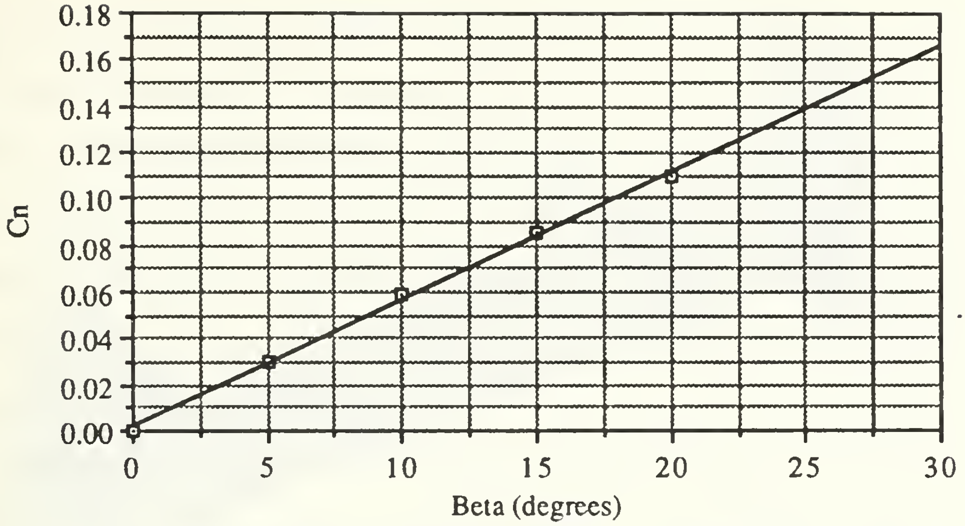


Figure 31. PIONEER - Cn vs Beta

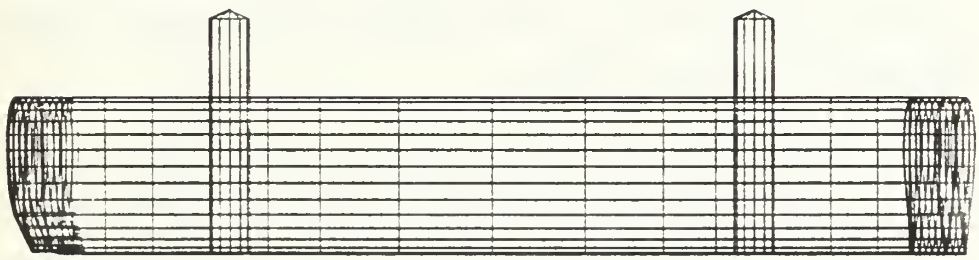


Figure 32. PIONEER Large Tail, 20° Single Rudder Deflection, 5° Up Elevator

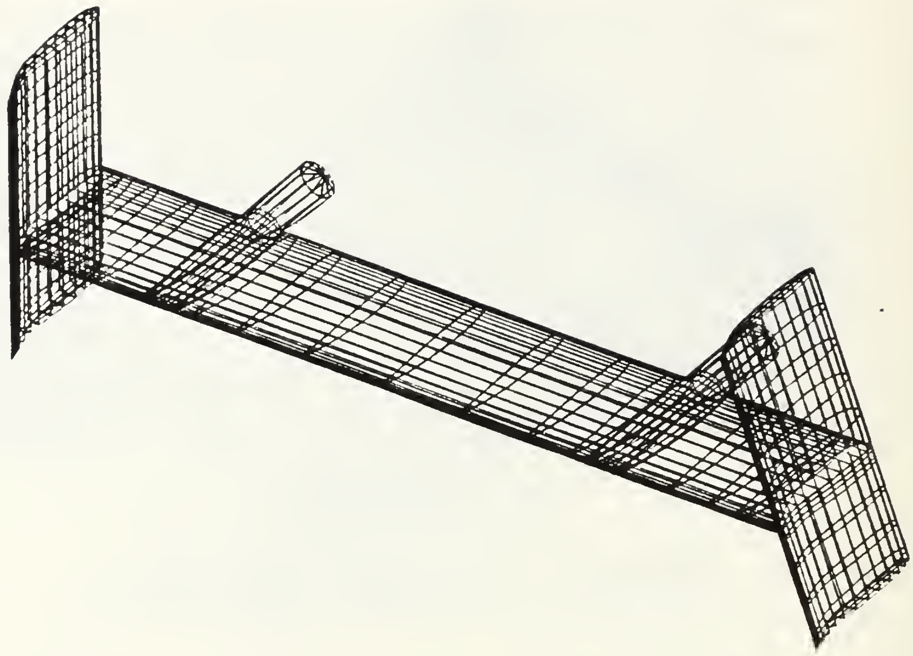


Figure 33. PIONEER Large Tail, 20° Dual Rudder Deflection, 5° Up Elevator

The tails were run at 0° sideslip, 7° angle of attack with 5° up elevator for rudder deflections of 5°, 10°, 15°, and 20 °. The resulting yawing moment coefficients for rudder deflections are shown in Figure 34.

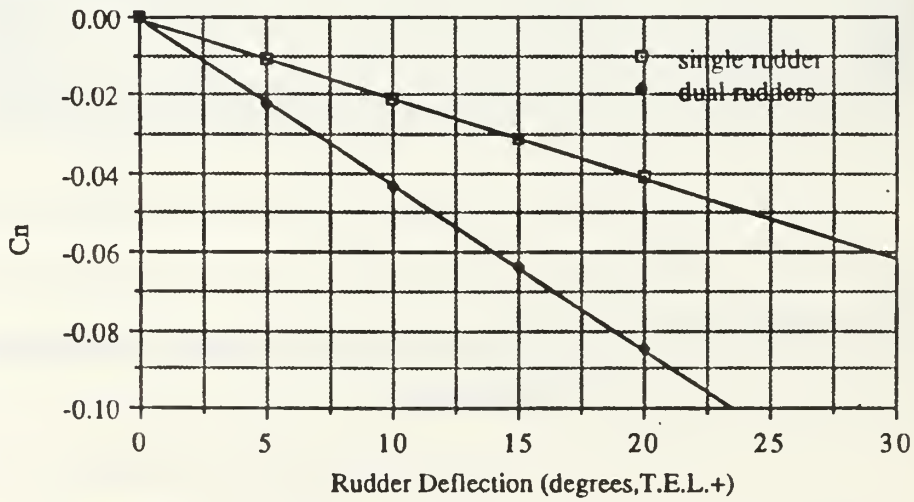


Figure 34. PIONEER - Cn vs Rudder Deflection

The accepted convention has rudder trailing edge left as positive [Ref 13: p.72]. The actual PMARC rudder deflection runs were for the case of negative rudder deflections (trailing edge right). Each of the vertical tail surfaces is symmetric which means that there will be no difference in the magnitude of the yawing moment coefficient for negative vice positive deflections. In order to be consistent with the example shown in Figure 29, the yawing moment coefficient was plotted as a function of positive rudder deflection.

With the yawing moment information available in Figures 31 and 34, it was possible to calculate trim rudder deflections for the single rudder and dual rudder configurations as a function of sideslip angle (Figure 35).

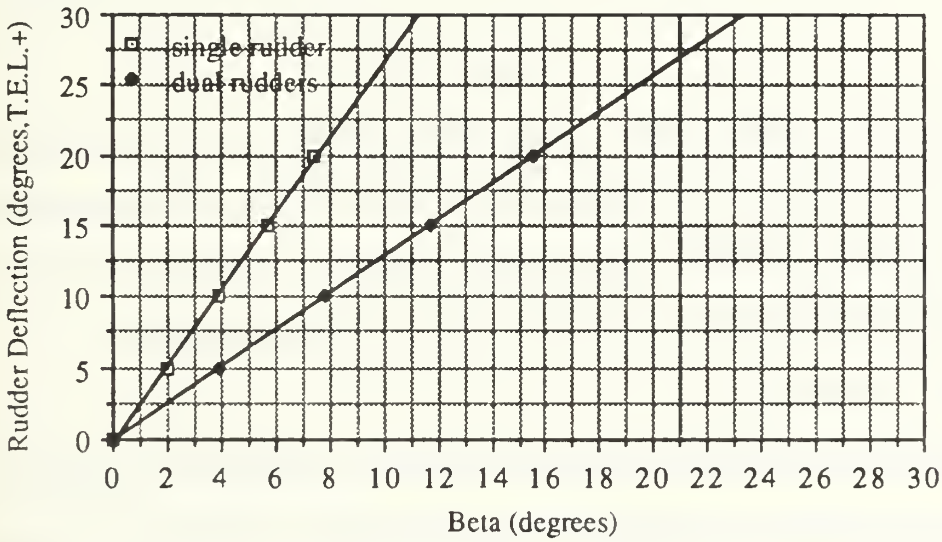


Figure 35. PIONEER - Rudder Trim vs Beta

For the case of 23° maximum rudder deflection, the maximum allowable sideslip angles for cross wind landings are 8.5° for the single rudder case, and 18° rudder for the dual rudder case.

With the maximum cross wind sideslip angle set, the cross wind limit becomes a function of approach speed. This is valid assuming that the different elevator trim

positions for various approach speeds would not change appreciably the yawing moment produced by the vehicle and rudders. Figure 36 shows the values of cross wind limit for various approach speeds.

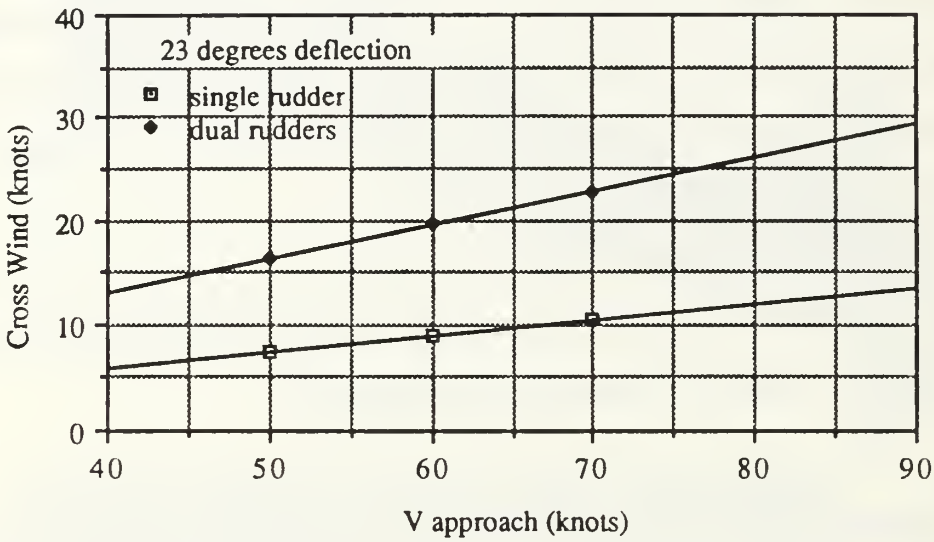


Figure 36. PIONEER - Cross Wind Limit vs Approach Speed

It should be noted, that the yawing moment due to sideslip will be somewhat less with the rudders deflected. This causes the above plot to be an even more conservative analysis of cross wind limitations than discussed earlier.

B. DRAG ESTIMATE

Part of the aerodynamic analysis of PIONEER consisted of predicting the drag on the vehicle. This was accomplished using PMARC to predict the inviscid drag and using the techniques described in Fluid Dynamic Drag by Hoerner [Ref. 14] to obtain an estimate of the viscous drag.

PMARC does not model viscous effects on the surface geometry. A routine which will take into account boundary layer interaction is currently being developed. PMARC will model the effects of induced drag and pressure drag. Figure 37 shows a drag polar for PIONEER for both tail configurations.

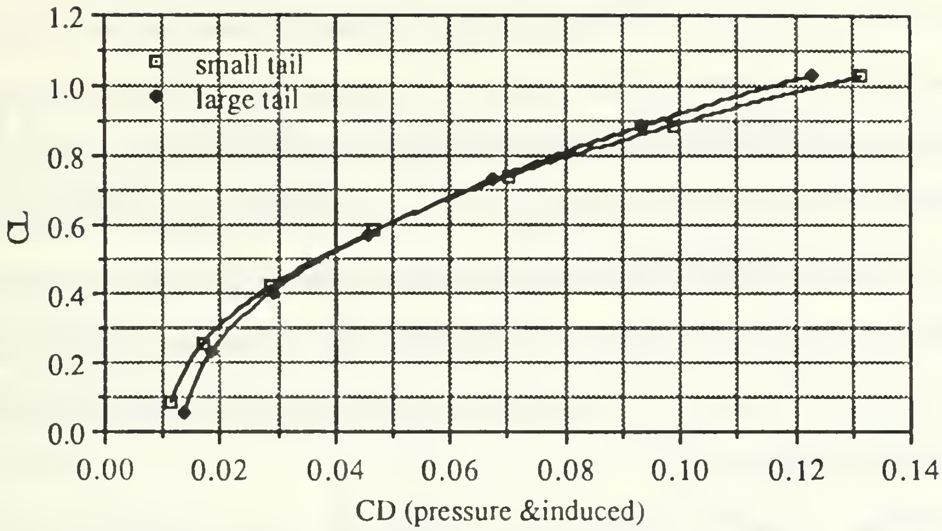


Figure 37. PIONEER - CL vs CD (Pressure and Induced)

Note that at the zero lift condition, where induced drag is zero, pressure drag is still present.

In order to obtain a complete drag polar, viscous effects needed to be addressed. Fluid Dynamic Drag by Hoerner uses a combination of theory and experimental results to estimate the drag contribution of every part of the vehicle as well as the effects of one vehicle component on another (interference drag) to obtain the net drag acting on the vehicle. Hoerner estimates of induced and pressure drag were not needed due to the PMARC analysis. The drag analysis using Hoerner was broken down into three areas: 1) the drag due to skin friction and interference; 2) the drag due to separation; and 3) the drag due to surface imperfections. With the exception of the interference drag, most of the calculations from Hoerner involved a skin friction coefficient, which is Reynolds number dependent. Since drag would be of most concern in a cruise configuration, a representative cruise speed of 75 knots was used for calculating the Reynolds number, which was calculated to be 1.35 x 10^6 using a chord length of 1.8 feet and an air density of .002368

slugs/cubic foot. All drag coefficients obtained during the analysis were adjusted so that the reference drag area was the wing area S. Appendix A lists the equations and their respective page numbers which were used to generate the viscous drag terms.

Table 3 shows the results for the profile and interference drag. The profile drag consists of drag due to skin friction and separation. The local reference area for this type of drag is wing area except for the friction drag on the "non-lifting" surfaces where wetted area is used. The largest contribution for this part of the analysis comes from the main wing.

Table 4 lists the calculated drag due to separation from components which are essentially bluff bodies. The local reference area for this type of drag is the frontal area of the component. The large drag contributors for this type of drag are the fuselage base drag, the separation from the nose landing gear, and the separation drag from the camera bubble on the bottom of the vehicle.

Table 5 lists the drag that is caused by what Hoerner calls imperfections on the surface of the vehicle. The largest drag contribution from the surface imperfections comes from the longitudinal gaps associated with the vehicle's control surfaces.

Table 6 shows the contributions from each of the types of drag listed above. The total viscous drag consists of all of the drag acting on the vehicle with the exception of pressure and induced drag. The largest overall contribution to the drag acting on PIONEER comes from the separation drag.

The viscous drag coefficient, referenced to the wing area of the vehicle, was added to the drag polar calculated by PMARC. Figure 38 is a drag polar representing all of the viscous and non-viscous forces which act on the vehicle.

TABLE 3. PIONEER - PROFILE & INTERFERENCE DRAG

Drag Component (Type)	C_D	Area (ft^2) S (w-wetted)	C_D*S/Swing
Wing (Profile)	.01115	30.50	.01115
Wing&Fuselage (Interference)	.0037	30.50	.00370
Fuselage (Friction)	.00476	20.42 (w)	.00319
Boom (Friction)	.00419	7.27 (w)	.00100
Vertical Tail (Profile)	.0105	3.87	.00130
Vertical Tail (Interference)	.00084	3.87	.00011
Small Horizontal Tail (Profile)	.0105	2.97	.00102
Small Horizontal Tail (Interference)	.00084	2.97	.00008
Large Horizontal Tail (Profile)	.0105	5.198	.00179
Large Horizontal Tail (Interference)	.00084	5.198	.00014
Pioneer (Small Tail) Subtotal:			.02130
Pioneer (Large Tail) Subtotal:			.02238

TABLE 4. PIONEER - SEPARATION DRAG

Drag Component	C_D	Area (ft^2) S (f-frontal)	C_D*S/Swing
Fuselage	.4266	.6727 (f)	.00941
Landing Gear - Main	.2500	.3233 (f)	.00265
Landing Gear - Nose	1.1600	.2131 (f)	.00810
Boom	.448	.1 (f)	.00147
Main Antenna	1.2	.14 (f)	.00551
Catapult Guides	.13	.0775 (f)	.00033
Position Lights	.32	.1507 (f)	.00158
Camera Bubble	.47	.5478 (f)	.00840
Pioneer Subtotal:			.03745

TABLE 5. DRAG DUE TO SURFACE IMPERFECTIONS

Drag Component (Type)	C_D	**Area (ft^2) S (f-frontal)**	C_D***S/Swing**
Rivets&Protrusions	.32	.0767 (f)	.00080
Spanwise Gaps:			
Ailerons	.00025	.0188	1.54x10^-7
Rudders	.00025	.2120	1.74x10^-6
Elevators (Small Tail)	.00025	.1278	1.047x10^-6
Elevators (Large Tail)	.00025	.2236	1.83x10^-6
Rudder Servos	.00025	.0276	2.27x10^-7
Longitudinal Gaps:			
Ailerons	.5	.1113	.0018
Rudders	.5	.0602	.0010
Elevators (Small Tail)	.5	.0451	.00074
Elevators (Large Tail)	.5	.0451	.00074
Pioneer (Small Tail)			
Subtotal:			**.003598**
Pioneer (Large Tail)			
Subtotal:			**.003599**

TABLE 6. PIONEER - TOTAL VISCOUS DRAG

Drag Type	Pioneer (large tail)	Pioneer (small tail)
Profile & Interference	.02238	.0213
Separation	.03745	.03745
Surface Imperfections	.003599	.003598
Total Viscous Drag	**.06343**	**.06234**

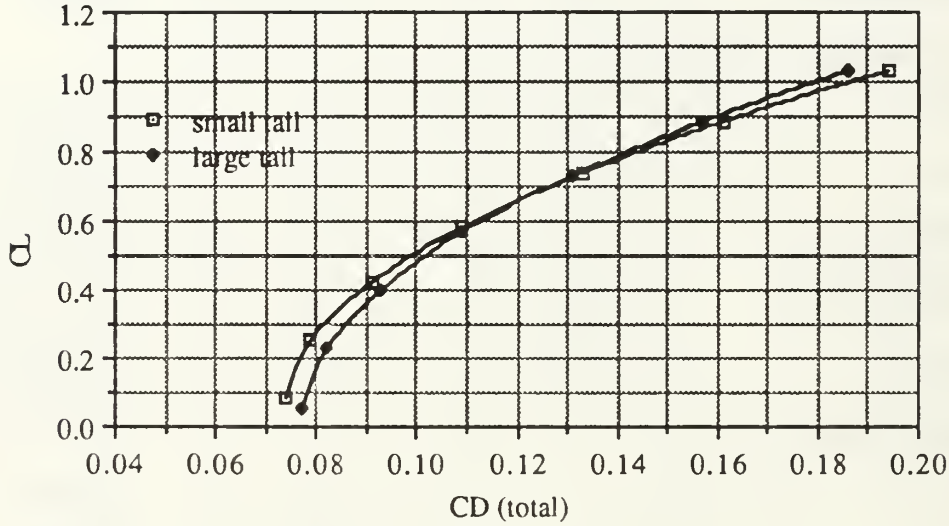


Figure 38. PIONEER - CL vs CD (Total)

It was noted earlier that the range and endurance of PIONEER is less than predicted by the manufacturer. One of the possible reasons for this could be poor drag predictions during the original design. Hoerner lists several methods which can be used to reduce the overall drag on a vehicle. Since PIONEER is already in fleet service and not in its development phase, drag reduction modifications to the vehicle need to be of a simple nature. Table 7 lists drag components on PIONEER which can be modified without major changes to the vehicle.

TABLE 7. PIONEER - DRAG REDUCTION

Drag Component (Type)	Drag Reduction Mechanism	Potential C_D Reduction	C_D Reduced By:
Wing/Fuselage (Interference)	Fillets	70%	.00259
Landing Gear-Main (Separation)	Fairings	53.4%	.00141
Landing Gear-Nose (Separation)	Fairing	53.4%	.00432
Boom (Base, Separation)	Fillets	100%	.00147
Main Antenna (Separation)	Streamlined Sleeve	80%	.004408
Camera Bubble (Separation)	Streamlined vice Spherical Bubble	50%	.0042
Spanwise Gaps	Elastic Covering Over Gaps	100%	3.168x10^-6
Total C_D Reduction:			**.0184**

Not surprisingly, most of the drag savings come from the area of highest drag contribution to the vehicle, separation drag.

Table 8 shows that a drag reduction of approximately 29% can be achieved.

TABLE 8. PIONEER (WITH REDUCED DRAG) - TOTAL VISCOUS DRAG

	Pioneer (large tail)	Pioneer (small tail)
Total Viscous Drag With No Drag Reduction:	.06343	.06234
Total CD Reduction:	.0184	.0184
Total Viscous Drag With Drag Reduction:	.04503	.04394
Percent of Drag Reduction:	**29%**	**29.5%**

Most of the drag savings could be achieved with little weight gain to the vehicle, and without major expense. The greatest savings would come from fiberglass fillets and fairings which could be produced at a designated depot repair facility. Manufacturing a new camera bubble would be a more complex task than the other modifications. Perhaps one simple modification would be to attach a clear plastic streamlined cover from the rear of the bubble to the fuselage.

IV. FOLLOW ON ANALYSIS OF PIONEER

A. NAVAL POSTGRADUATE SCHOOL UAV FLIGHT TEST RESEARCH PROGRAM

The Naval Postgraduate School Department of Aeronautics and Astronautics currently has a flight test program which involves smaller scale UAV's, one of which is a half-scale PIONEER. The purpose of the overall program is to establish procedures to evaluate vehicle performance on scaled flight vehicles and to investigate ways to improve that performance. Information will be gained through flight testing the half-scale PIONEER, which will augment the current full-scale PIONEER flight testing which is underway at PMTC.

1. Program Overview

The half-scale flight test program completed its first phase in March 1989 with work done by Tanner [Ref 15]. Tanner developed the methodology to obtain aerodynamic performance of the vehicle with regards to drag and thrust measurements. Test flights of the half-scale PIONEER were conducted from which a drag polar of the vehicle was obtained. The work completed in phase one of the Naval Postgraduate School UAV Flight Test Program has laid the groundwork for more complete testing of the vehicle.

The instrumentation used for the first phase of testing consisted of a tape recorder to record engine RPM from a magnetic proximity transducer positioned next to a toothed sprocket on the engine crankshaft. These data were used with the results of torque tests and wind tunnel thrust tests to determine drag coefficients. Lift coefficients were acquired knowing the aircraft weight and airspeed. The vehicle is currently being modified to carry a three-axis rate-sensor package which will allow

accurate measurements of pitch and roll angles and pitch, yaw, and roll rates and accelerations. Rudder and elevator deflection angles will be obtained during flight from data collected from the potentiometers inside the control surface servos. After modifications to the vehicle are complete, flight testing will be conducted to validate the PMARC predictions from this study.

2. Full-scale Drag Modeling

A drag analysis was conducted for the half-scale PIONEER using the technique used for the full-scale vehicle analysis and the results were compared to the flight test results from phase one of the half-scale PIONEER flight test program. The inviscid part of the drag analysis gives identical results to the full-scale, small tail PIONEER drag analysis. The induced and pressure drag from PMARC are not dependent on Reynolds number effects and are directly applicable to the half-scale vehicle.

For the viscous part of the analysis, a Reynolds number of .54x10^6 was used based on a half-scale vehicle cruise speed of 60 knots and a reference chord length of .93 feet. The skin friction coefficient from the half-scale Reynolds number was .0018 in comparison to the .00419 value for the full-scale/higher Reynolds number analysis. The half-scale Reynolds number is in a flight regime where flow is predominantly laminar, whereas the full-scale Reynolds number of 1.35x10^6 results in flow that is mostly turbulent. The differences between these two flow regimes will be pointed out in the following analysis.

Table 9 shows the profile and interference drag results from Hoerner.

TABLE 9. PIONEER (HALF-SCALE) - PROFILE & INTERERFENCE DRAG

Drag Component (Type)	C_D	Area (ft^2) S (w-wetted)	C_D*S/Swing
Wing (Profile)	.00479	15.25	.00479
Wing&Fuselage (Interference)	.00370	15.25	.00370
Fuselage (Friction)	.00200	10.21 (w)	.00134
Boom (Friction)	.00180	3.63 (w)	.00043
Vertical Tail (Profile)	.00451	1.937	.00057
Vertical Tail (Interference)	.00036	1.937	.00005
Small Horizontal Tail (Profile)	.00451	1.485	.00044
Small Horizontal Tail (Interference)	.00036	1.485	.00003
Large Horizontal Tail (Profile) NA			
Large Horizontal Tail (Interference) NA			
Pioneer (Small Tail) Subtotal:			**.01135**
Pioneer (Large Tail) Subtotal: NA			

A comparison between the half-scale and full-scale results show a much lower profile drag for the half-scale over the full-scale vehicle. This is due primarily to the reduced skin friction coefficient associated with the lower Reynolds number. The interference effects, however, are not affected by the Reynolds number and their contribution to the overall drag is the same for both the full-scale and half-scale vehicles.

Table 10 lists the separation drag from the half-scale analysis. Note that many of the high separation drag contributors for the full-scale vehicle, are not physically present on the half-scale vehicle.

TABLE 10. PIONEER (HALF-SCALE) - SEPARATION DRAG

Drag Component	C_D	**Area (ft^2) S (f-frontal)**	C_D***S/Swing**
Fuselage	.6834	.3364 (f)	.01507
Landing Gear - Main	.2500	.1615 (f)	.00265
Landing Gear - Nose	1.1600	.103 (f)	.00783
Boom	.6835	.05 (f)	.00220
Main Antenna NA			
Catapult Guides NA			
Position Lights NA			
Camera Bubble NA			
Engine Cylinder	1.2	.0208(f)	.00164
Engine Air Intake	.35	.0167	.00038
Pioneer Subtotal:			**.02977**

The largest difference between the full-scale and half-scale results for separation drag is the fuselage base drag. The half-scale fuselage base drag is 37.5% higher than the full-scale drag. The laminar flow tends to separate sooner than the turbulent flow, thus giving a larger area of separated flow. This early separation increases the drag as shown in the Hoerner analysis.

Table 11 shows the effects of surface imperfections on the vehicle, where it is seen that the lower Reynolds number flow reduces the effects of this type of drag.

TABLE 11. PIONEER (HALF-SCALE) - DRAG DUE TO SURFACE IMPERFECTIONS

Drag Component (Type)	C_D	Area (ft^2) S (f-frontal)	C_D*S/Swing
Rivets&Protrusions	.32	.00767 (f)	.00008
Spanwise Gaps:			
Ailerons	.00025	.0094	7.7x10^-8
Rudders	.00025	.106	8.7x10^-7
Elevators (Small Tail)	.00025	.0639	5.2x10^-7
Elevators (Large Tail)			
Rudder Servos			
Longitudinal Gaps:			
Ailerons	.5	.05565	.00091
Rudders	.5	.0301	.00049
Elevators (Small Tail)	.5	.02255	.00037
Elevators (Large Tail)			.
Subtotal:			**.00185**

Table 12 shows the total contribution to the viscous drag acting on the half-scale PIONEER.

TABLE 12. PIONEER (HALF-SCALE) - TOTAL VISCOUS DRAG

Drag Type	Pioneer (half-scale)
Profile & Interference	.01135
Separation	.02977
Surface Imperfections	.00185
Total Viscous Drag	**.04297**

The largest overall contributor to drag is the separation drag, as was the case for the full-scale vehicle. The largest overall Reynolds number effect difference between the full-scale and half-scale vehicles can be seen in the profile and interference drag. As was pointed out earlier, the interference drag contribution was the same for both vehicles. This means that the lower drag is the result of the reduced profile drag which is a direct function of the skin friction coefficient.

Figure 39 shows the results of the half-scale drag analysis along with data points from the half-scale flight test. The predicted values of drag parallel the flight test values but appear to be less in magnitude. The minimum drag coefficient, C_{Do}, from the PMARC/Hoerner analysis in Figure 39 is .053. This value is slightly higher than the value of .0516 found by Tanner from the half-scale flight test results [Ref 15: p. 57]. Despite the small difference of the two values, it appears that the C_{Do} predicted by the PMARC/Hoerner analysis needs to be an even higher value in

order for agreement between a majority of the flight test data and predicted values to take place.

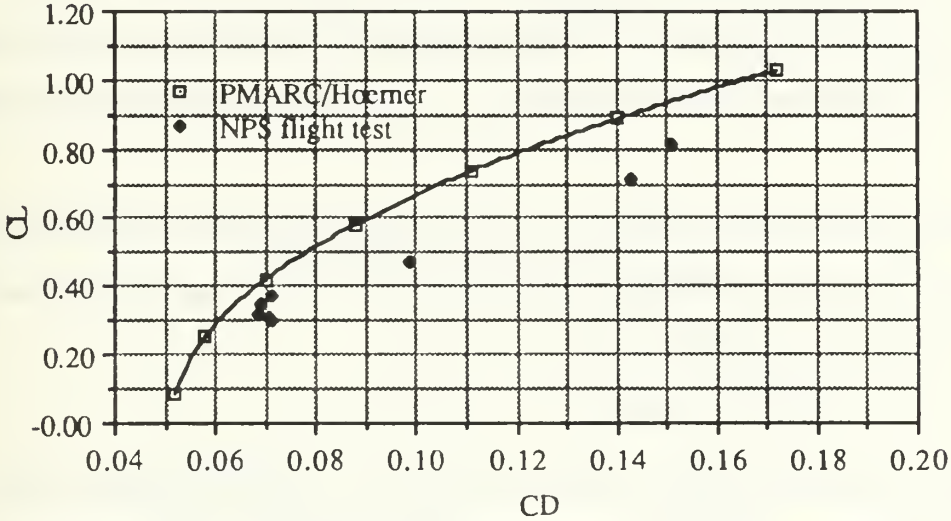


Figure 39. PIONEER (half-scale) - CL vs CD (Total)

Figure 40 shows the flight test data points, and the original PMARC/Hoerner predictions, along with the PMARC/Hoerner data shifted to two arbitrarily chosen values of C_{Do}: C_{Do} equal to .059, and C_{Do} equal to .079.

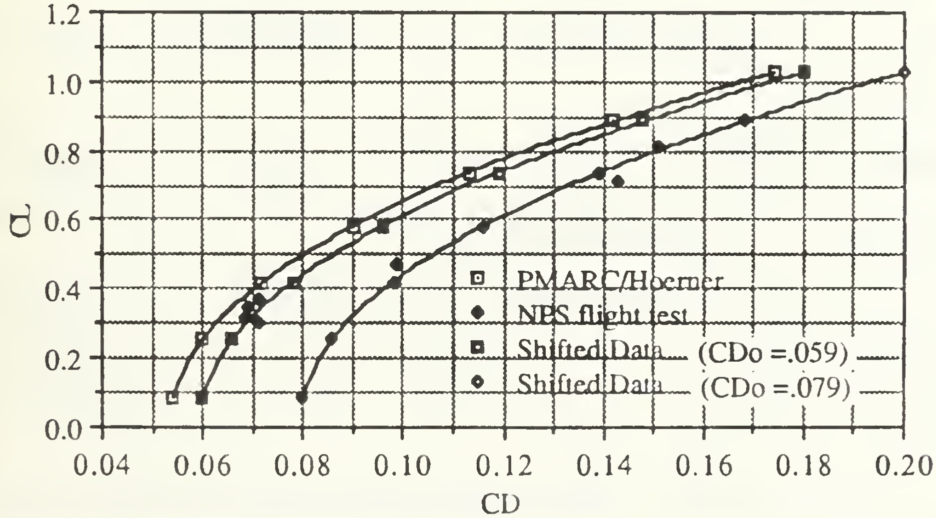


Figure 40. PIONEER (half-scale) - CL vs CD (Total)

With a C_{D_o} value of .059, the predicted drag values intersect the cluster of actual test values located at a C_D equal to approximately .07. The rest of the predicted values are lower than the actual test values at higher lift coefficients. By shifting the value of C_{D_o} to an even higher value of .079, the predicted values of drag are very close to the test values of drag except for the cluster of actual test values located at C_D equals .07.

As with the full-scale drag analysis, a study was made of how to reduce the drag acting on the half-scale PIONEER. Table 13 shows the areas where realistic and cost effective drag reductions can be made to the vehicle.

TABLE 13. PIONEER (HALF-SCALE) - DRAG REDUCTION

Drag Component (Type)	Drag Reduction Mechanism	Potential C_D Reduction	C_D Reduced By:
Wing/Fuselage (Interference)	Fillets	70%	.00259
Landing Gear-Main (Separation)	Fairings	53.4%	.00141
Landing Gear-Nose (Separation)	Fairing	53.4%	.00418
Spanwise Gaps	Elastic Covering Over Gaps	100%	2.938x10^-6
C_D Reduction:			**.00818**

As with the full-scale vehicle, most of the drag savings comes from reducing separation drag. The purpose in reducing drag for the half-scale vehicle is not for

operational reasons, but to evaluate drag reduction methods which would be applicable to the full-scale vehicle. Although the separation location is Reynolds number dependent, as discussed earlier, valuable information can be learned by looking at the relative amount of drag that can be saved by any one technique. Table 14 shows the potential overall drag savings to the half-scale PIONEER.

TABLE 14. PIONEER (HALF-SCALE WITH REDUCED DRAG) - TOTAL VISCOUS DRAG

	Pioneer (half-scale)
Total Viscous Drag With No Drag Reduction:	.04095
Total Cd Reduction:	.00818
Total Viscous Drag With Drag Reduction:	.03463
Percent of Drag Reduction:	19.0 %

Additional information could be learned about PIONEER by improved configuration modeling of the half-scale PIONEER to resemble the full-scale vehicle. In addition to adding antennas, a camera bubble, etc., an attempt could be made to model the full-scale vehicle drag behavior more accurately by forcing the flow regimes to resemble one another. One of the major reasons for the drag difference between the two vehicles is the separation point. Through the use of transition

strips, the flow over the half-scale vehicle can be artificially transitioned from laminar to turbulent, thus giving a more accurate model of the full-scale drag.

B. FULL-SCALE WIND TUNNEL TESTING

Full-scale wind tunnel testing would serve, not only to benefit the development of the PIONEER vehicle, but to validate the prediction and evaluation techniques being used in the study of PIONEER, which will be applicable to future UAV designs of similar configuration. Wind tunnel testing would help establish the low-speed longitudinal and directional maneuvering and controllability characteristics of PIONEER without risking the loss of a flight vehicle. An accurate drag polar of PIONEER would be obtained, which would provide an accurate means of validating or assessing the drag prediction techniques used in this study. Full-scale wind tunnel testing would eliminate the Reynolds number inconsistency present with the half-scale flight testing or small-scale wind tunnel testing. Finally, full-scale testing would help assess the validity of a half-scale UAV flight test program and the validity of a PMARC analysis for this type of vehicle configuration.

1. The National Full-scale Aerodynamics Complex

Inquiries were made about the various wind tunnels which would be capable of testing a full-scale PIONEER flight vehicle. Three facilities were contacted: NASA Langley Research Center, Lockheed Georgia, and the National Full-scale Aerodynamics Complex (NFAC) at the NASA Ames Research Center. The NASA Langley wind tunnels were determined to be undesirable due to: 1) the small size of the 14x22 foot wind tunnel; 2) the poor flow quality of the 30x60 foot wind tunnel with regards to low Reynolds number tests; and 3) incompatibilities between the PIONEER weight of 400 pounds and the available balances at the Langley facility. The Lockheed Georgia tunnels are unsuitable due to: 1) the lack of a balance system

for the 30x26 foot wind tunnel; 2) the lack of model support for the 30x26 foot wind tunnel; and 3) the small size of the 16x23 foot wind tunnel. Two tunnels are located at the NFAC which would be suitable for the proposed testing of PIONEER. The proposed schedule for the 40x80 foot wind tunnel and the priority placed on those tests, makes it an unlikely candidate for full-scale testing of PIONEER. The schedule for the 80x120 foot wind tunnel at the NFAC is such that testing of PIONEER could be accomplished in the near future. The tunnel speed capabilities of the 80x120 foot wind tunnel are compatible with the flight regime of PIONEER. In addition, test hardware is available which would mount the vehicle in the tunnel and would allow measurement of the aerodynamic forces and moments acting on the vehicle.

2. Wind Tunnel Mount

The strut mounts normally used in the 80x120 foot wind tunnel are so large in comparison to PIONEER, that the relatively small forces and moments acting on the vehicle would be overshadowed by the large drag on the strut mounts. An alternative method of mounting the vehicle in the tunnel would be necessary for a successful wind tunnel test. A sting mount, which was formally used in the 40x80 foot tunnel, is available for modification for the PIONEER test. A sting mount normally is placed into the tail section of the vehicle. Because of the configuration of PIONEER and the proposed powered test, this method of placing a vehicle on a sting mount was deemed unsuitable. Figure 41 depicts PIONEER mounted in the 80x120 foot tunnel using the modified sting mount. By placing PIONNER in a static 90° roll position, the vehicle can be mounted with a minimum of interference while allowing the engine to be run. A test mount which was used in the 80x120

foot wind tunnel test of a tractor trailer, could readily be adapted to mount the sting mount in the tunnel.

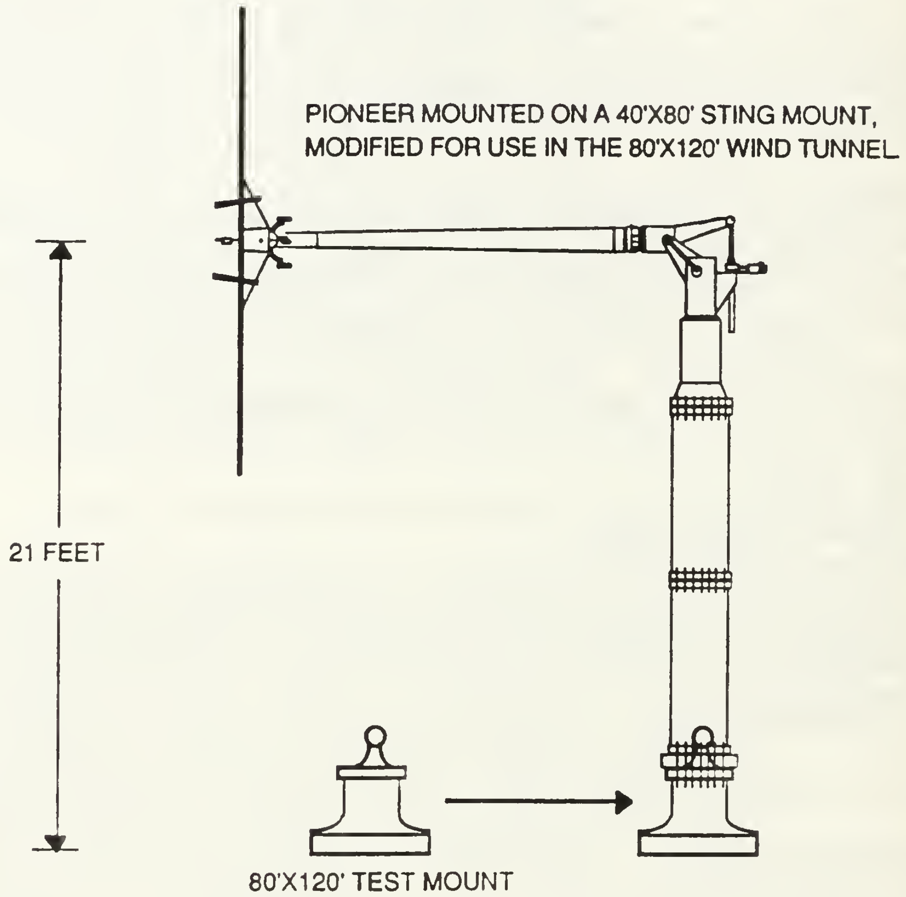


Figure 41. PIONEER Mounted in the 80'x120' Test Section

3. Measurement of Moment and Forces

The floor balances normally used for measuring forces and moments in the 80x120 foot wind tunnel are designed for much larger flight vehicles than the PIONEER. The accuracy of the large balances for relatively small forces, such as would be encountered during full-scale testing of PIONEER, would be unacceptable. The sting mount adapted for testing of PIONEER was designed to be used with an eight-inch six-component internal strain gage balance. This balance

would be too large for the proposed test, but the mount is readily adaptable to a smaller balance. Smaller internal six-component strain gage balances, appropriate to the aerodynamic forces and moments expected from wind tunnel testing of PIONEER, are available at the NFAC. Figure 42 is a top view of PIONEER mounted on the 40x80 foot wind tunnel sting mount.

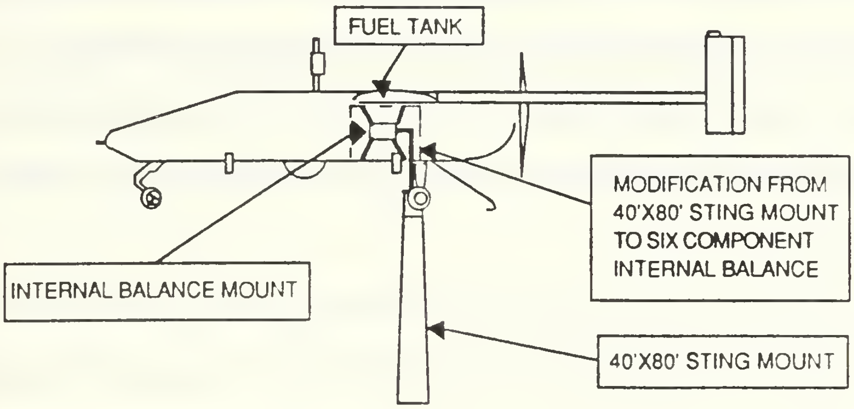


Figure 42. Top View of PIONEER Mounted With a Six-Component Strain Gage Balance

Attached to the mount is an adapter which would fit into the slot designed for the eight-inch balance. The adapter proceeds straight from the end of the mount, up into the test vehicle, where it has a 90° elbow pointed towards the front of the vehicle. The internal strain gage balance is attached to the end of the adapter. The above figure shows the strain gage balance inside of the internal balance mount, which is securely attached to the inside of the fuselage fuel tank of the vehicle. This mounting scheme involves cutting into the bottom of the fuselage, where the fuel tank is located.

4. Safety Considerations

Safety is a primary concern in full-scale wind tunnel testing of flight hardware. When models are built for wind tunnel use, they can be built as strongly

as needed to insure an adequate safety factor. This precaution is not an option when testing an actual flight vehicle. The structural integrity of the vehicle and mount system must be without question prior to any wind tunnel test. One option to insure vehicle integrity would be to obtain a complete structural analysis from the manufacturer. Of primary concern is the fact that in wind tunnel testing, many of the normal loads experienced by the flight vehicle are reversed in wind tunnel testing: compressions become tensions, etc. Another option would be to perform static load testing of the vehicle prior to testing. This could even be accomplished using sand bags distributed over the structure to simulate the aerodynamic loads expected during the test.

Since a powered test is proposed, another primary concern is fire safety. Normally, fuel for powered tests is pumped from a storage tank outside of the tunnel, up to the test vehicle engine. It is estimated that only two gallons of 100-octane aviation fuel will be needed for each test run. It appears safer to hold this small amount of fuel on board the vehicle in a modified gas tank. The modified tank is necessary because of the method of mounting the vehicle as mentioned earlier. An additional safety feature would be added in the form of an on board remotely-operated fire extinguisher.

5. Test Program

It is estimated that two weeks of wind tunnel time will be needed to mount the vehicle in the tunnel, calibrate all of the instrumentation, conduct the test, and remove the test equipment from the tunnel. Once the vehicle is mounted in the tunnel, as depicted in Figure 41, the test will be conducted, running PIONEER through a series of configurations at various angles of attack. The change in angle of attack will be accomplished by rotating the table on the wind tunnel floor, which in

turn will cause the vehicle mount to rotate. Changes in sideslip angle will be accomplish manually. The adapter to the 40x80 foot wind tunnel sting mount will need to be manufactured with keyed slots to facilitate rotating the vehicle through four sideslip angles: 5°, 10°, 15°, and 20°. Testing the vehicle in pitch and yaw will allow the longitudinal and directional stability and control derivatives of the vehicle to be obtained. Component testing will be accomplished to identify high drag contributors. In addition, any drag reduction techniques which come about from the Naval Postgraduate School UAV Flight Test Research Program could be implemented and verified. PMTC will provide an actual PIONEER flight vehicle for the test.

V. CONCLUSSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Past military operations have shown that the utilization of UAV's can mean the difference between success or failure. The U.S. Navy and Marine Corps recognized the need for a UAV system and procured the PIONEER system in a relatively short amount of time. In order to have an operational UAV system in the fleet quickly, a concurrent acquisition program was pursued, where fleet introduction was concurrent with the beginning of developmental testing on the vehicle. This "Quick-Go" approach was at the expense of an adequate development period. Fleet operations and developmental testing have pointed out various aerodynamic deficiencies in PIONEER, specifically: low speed longitudinal and directional controllability difficulties, restricted "allowable" cg locations, and questionable drag predictions, which affect range and performance predictions. In addition to the questions about its low speed controllability characteristics, some of PIONEER's shipboard difficulties were possibly attributed to ship airwake turbulence. Study of the turbulence effects of ships on the landing capabilities of PIONEER, or UAV's in general, could reduce losses of UAV's in the future.

The low-order panel method, PMARC, was used to analyze the aerodynamic performance of PIONEER. Various plots of PIONEER aerodynamic performance were constructed based on the results of the PMARC analysis on different vehicle configurations. Trim elevator deflections were predicted as a function of lift coefficient as were trim rudder deflections versus sideslip angle. Flight testing and

wind tunnel testing would provide simple means of validating this PMARC analysis of PIONEER.

An evaluation of the longitudinal stability and control of PIONEER showed that the neutral point for the large tail configuration is 74%MAC and 51%MAC for the small tail PIONEER. Table 1 shows that PIONEER at a cg location of 33%MAC is similar to other aircraft types, with regards to the longitudinal stability and control derivatives. It was shown that the cg location could be located at 54%MAC for the large tail PIONEER and at 29%MAC for the small tail PIONEER and exhibit pitch stability similar to that of a Cessna 172.

An evaluation of the vehicle's directional stability and control showed a cross wind sideslip limitation of 8.5° for the single rudder case and a limitation of 18° sideslip for the dual rudder case. For an approach speed of 65 knots, this limitation equates to a cross wind limit of ten knots for the single rudder case and 22 knots for the dual rudder case.

Two items which were obtained as a by-product of this study are the rolling moment coefficients due to sideslip and due to rudder deflection. These values, as shown in Table 1, seem higher than the values for other aircraft.

A drag analysis of PIONEER was performed using PMARC and the techniques described in Fluid Dynamic Drag by Hoerner. Complete drag polars of the vehicle were constructed. Most of the viscous drag could be attributed to separation of the flow from the various drag components on the vehicle. It was determined that cost effective and simple drag modifications to the vehicle could be made which could effect a 29% reduction in the overall vehicle drag.

Drag predictions were made for the half-scale PIONEER using the same techniques used for the full-scale vehicle. One of the most obvious results was the

reduction in drag due to the laminar flow associated with the lower Reynolds number. Although the turbulent flow of the full-scale vehicle can not be "transitioned" to laminar flow, laminar flow airfoils are in existence which could be incorporated in future designs. The only difficulty, from an operational stand point, would be the necessity to keep the wing free from dirt, bugs, etc. which would serve to transition the flow from laminar to turbulent, thus negating the benefit of a laminar flow wing.

The predicted drag data for the half-scale PIONEER paralleled the flight test results but did not correlate exactly. The PMARC/Hoerner predictions were shifted arbitrarily to investigate the possibility that the viscous drag estimation was in error. Two separate estimations, based on the PMARC/Hoerner predictions, showed good correlation with parts of the data. The relatively few and scattered flight test data points do not allow a definitive judgement to be made concerning the accuracy of the drag study which was performed on the half-scale PIONEER. More flight test data are needed so better confidence can be gained in the actual half-scale drag which in turn will show how valid the PMARC/Hoerner predictions are.

B. RECOMMENDATIONS

Before changes can be made to the operating envelope of PIONEER based upon this study, some validation of the techniques used must be made. An operational or test flight should be conducted for a vehicle whose cg is located at 33%MAC. The lift coefficient should be calculated for various airspeeds and the trim elevator position should be recorded. Correlation between the predicted (Figures 27 and 28) and actual values should suggest confidence in the rest of the analysis. Additional confidence can be obtained by checking the ability of the flight

vehicle to produce a certain sideslip angle for a given rudder deflection as shown earlier in Figure 35.

Once validation of this study has been made, a program should be set up to expand the "allowable" cg locations. This study shows that the aft cg restriction of 37%MAC can without question be expanded. Positive static longitudinal stability is predicted back to the aft cg location of 74% for the large tail PIONEER and 51% for the small tail PIONEER. For a given cg location, Figures 21 and 22 show the pitching moment change with angle of attack. The value obtained from those figures for pitching moment change with angle of attack can be compared with other aircraft listed in Table 1 to give some indication of the type of pitch response that will be obtained for a specified cg location.

The cross wind values presented in Figure 36 show that the cross wind limitation of the single rudder configuration is less than 15 knots even at an approach speed of 90 knots. It is recommended that only the dual rudder configuration be used on operational PIONEER vehicles.

A PMARC analysis of PIONEER to investigate the rolling characteristics of the vehicle should be pursued. The seemingly high values of rolling moment due to sideslip and rudder deflection as shown in Table 1 warrant further study.

In order to facilitate the correlation of the drag prediction techniques used in this study, it is recommended that more drag data points be obtained from the Naval Postgraduate School UAV Flight Test Research Program. The half-scale PIONEER should be physically modified to model the full-scale vehicle to aid in studying drag reduction techniques. Work should be done in modelling the flow regime of the full-scale vehicle through the use of transition strips. Various drag reduction mechanisms should be tested on the half-scale PIONEER to include fillets, landing

gear fairings, streamlining of all bluff bodies, and covering of any spanwise gaps. If drag savings prove to be as significant as predicted, modifications to the full-scale PIONEER should be pursued.

Modifications to the half-scale PIONEER's instrumentation package should continue. Flight tests should be conducted as soon as possible to evaluate the longitudinal and directional stability and control performance predicted in this study.

Flow visualization work is currently being conducted by the Naval Postgraduate School Department of Aeronautics and Astronautics on ship airwake turbulence problems. It is recommended that this work be extended to study the turbulence associated with shipboard recoveries of PIONEER.

Full-scale wind tunnel testing should be pursued through the Navy-NASA Joint Institute of Aeronautics. Wind tunnel testing would allow accurate drag information on PIONEER to be obtained. A better understanding of how half-scale flight test drag reductions can be applied to the full-scale vehicle would also be obtained. Wind tunnel testing would provide an expedient means to evaluate drag reduction modifications to the full-scale vehicle. Full-scale testing of PIONEER will validate the techniques used in this study. A valid analysis of PIONEER will mean that the U.S. Navy and Marine Corps have a proven and systematic method by which to evaluate current and future UAV's of a similar configuration.

APPENDIX A

HOERNER: DRAG ANALYSIS

The following appendix contains the equations and page numbers from Fluid Dynamic Drag by Hoerner, which were used in the viscous drag calculations.

WING SURFACES: CD(profile) = 2Cf + 4Cf(t/c) +120Cf(t/c)^4 [p. 6-6, eq.6]

FUSELAGE: CD(wetted area) = Cf + 1.5Cf(d/l)^3/2 + 7Cf(d/l)^3 [p. 6-18, eq. 28]

FUSELAGE BASE DRAG: CDB = .029/SQR(Cf) [p.3-19, eq. 34]

BOOM: CD (wetted area) = Cf

MAIN WING INTERFERENCE: [p. 8-15, figure 36]

TAIL INTERFERENCE: [p. 8-12, figure 28]

MAIN LANDING GEAR DRAG: [p. 13-14, figure 35]

NOSE LANDING GEAR DRAG: [p. 13-15, figure 37]

MAIN ANTENNA DRAG: [p. 13-19, figure 50]

CATAPULT RAILS: [p. 13-19, figure 50]

RIVETS/PROTRUSIONS/LIGHTS: [p.5-8, figure 14]

CAMERA BUBBLE: (half of the frontal area of a complete sphere was used for the frontal area calculation) [p. 3-17, figure 33]

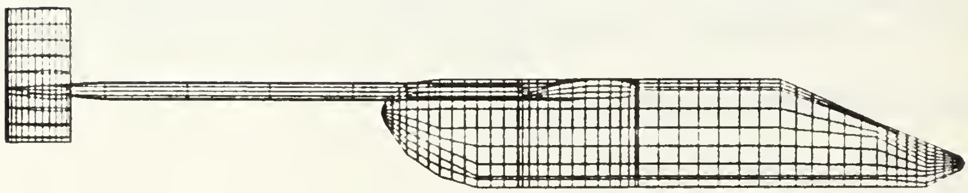
LONGITUDINAL GAPS: [p. 5-12]

SPANWISE GAPS: [p. 5-13]

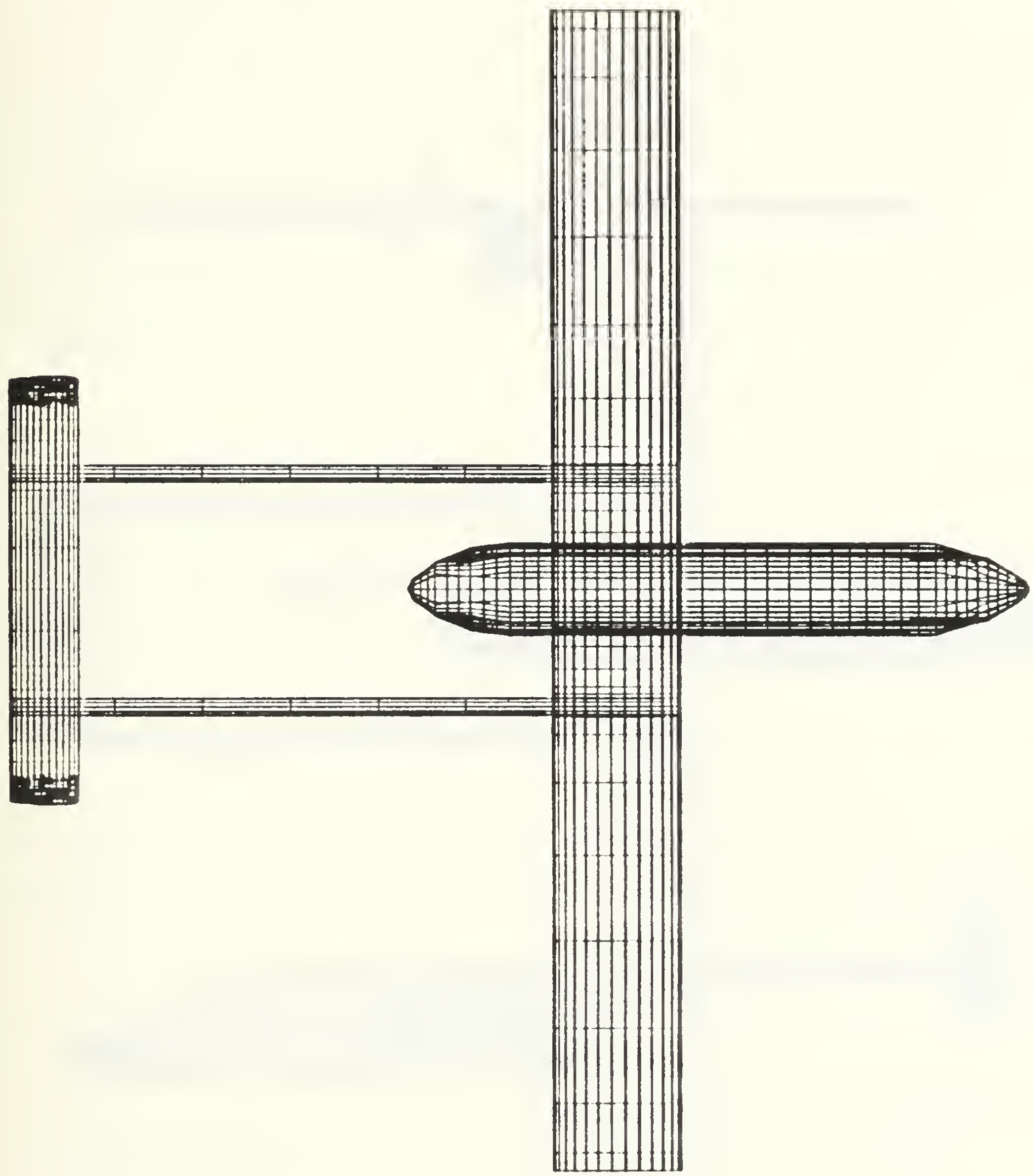
APPENDIX B

PIONEER 3-VIEW (PMARC/PAD)

PIONEER (large tail) - Front View

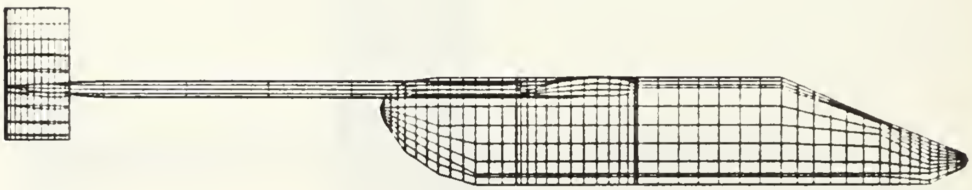


PIONEER (large tail) - Side View

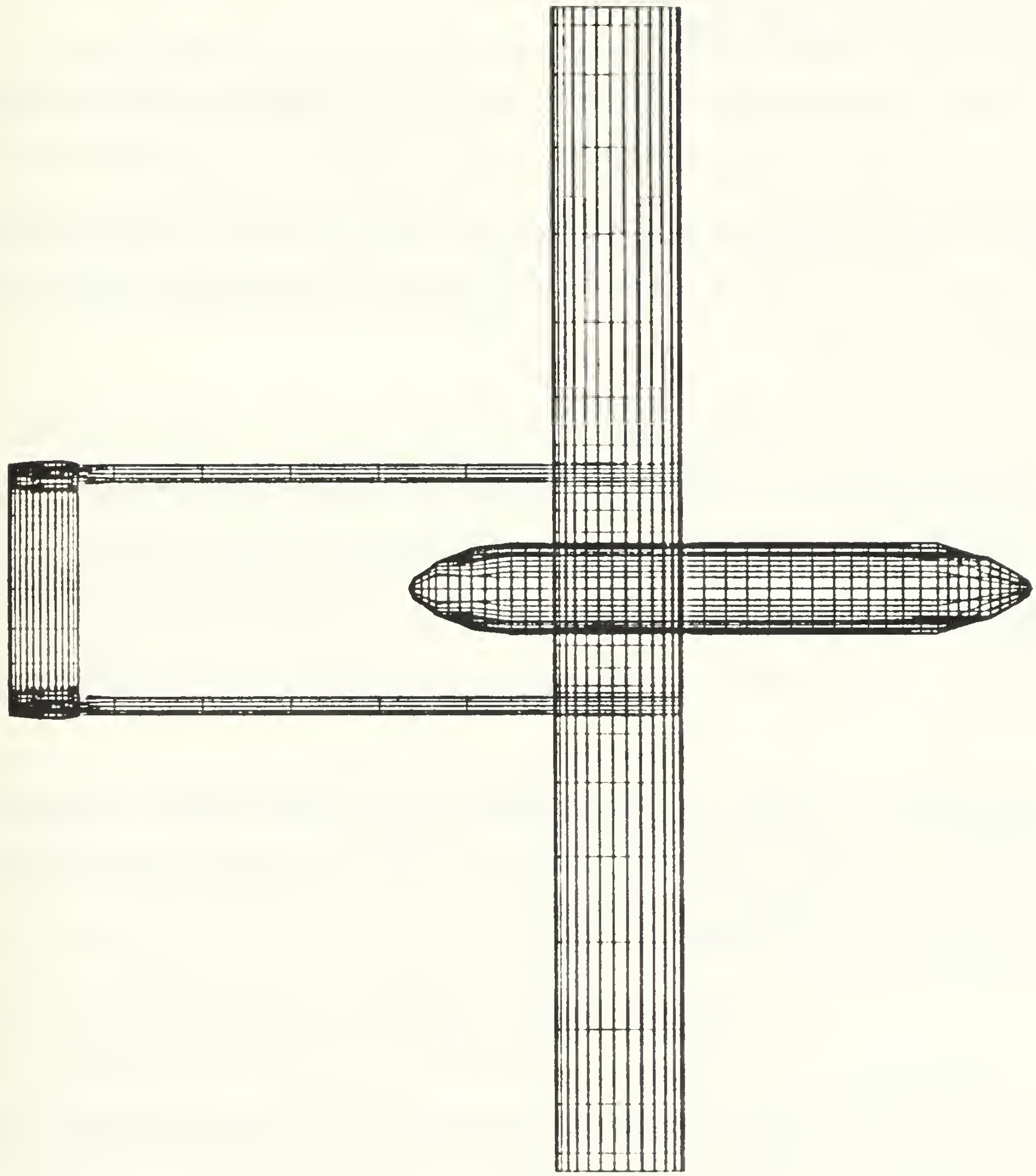


PIONEER (large tail) - Top View

PIONEER (small tail) - Front View



PIONEER (small tail) - Side View



PIONEER (small tail) - Top View

APPENDIX C
PMARC/PAD USERS GUIDE FOR THE CAD/CAE LABORATORY

SOFTWARE OVERVIEW

Various files have been set up on the MicroVAX CAD/CAE Computer network in the RUN DIRECTORY: WASP$DUA0: [LYONS]. The executable codes and command procedures were obtained from the NASA Ames Research Center. The following will serve to give a description of the files as they pertain to the execution of PMARC and PAD:

ASPFONT.DAT: This file is necessary for the PAD plotting routine to run. ASPFONT.DAT is a binary data file of 777 blocks in length which contains the Hershey fonts used to plot symbols and text. It can reside in the SYSTEM LIBRARY or in the same RUN DIRECTORY as the PAD executable code.

PMARC_10.FOR: This file contains the PMARC source code which is specifically modified for the MicroVAX. Linking the source code produces the object and executable PMARC_10 code.

TCS.OLB: The Tektronix TCS (Terminal Control System) library allows PAD to execute on screen plotting. This proprietary program is linked with the PAD object code to produce the PAD executable code. TCS.OLB would normally reside in the system file, but is unnecessary since the executable code was

obtained.from the NASA Ames Research Center, once TCS was purchased from Tektronix.

E7.JOB: This file contains the input data for modelling the experimental E7 VTOL aircraft mounted in the NASA Ames National Full Scale Aerodynamics Complex 40 X 80 Wind Tunnel.

TESTA.JOB: This file contains the input data for modelling a NACA four digit airfoil with a time stepping shed wake.

PADEXE.COM: This command file sets the directory hosting the PAD executable code, cleans up excess files, and sets up DIP (Device Independent Plot) files. It is necessary to edit this file to define the correct directory/ subdirectory. PAD is executed from running this command procedure using the command @PADEXE.COM.

PAD.EXE: This is the executable, already linked PAD code. The TCS library has already been linked to the program at NASA Ames. PAD can be run separately from the PAD command file once the run directory is set manually and once the file ,USERLOC.DAT, is manually created (see PADEXE.COM).

DIP AND OTHER PLOTTING PROGRAMS: In addition to on screen plotting, PAD creates Device Independent Plot (DIP) files which allow direct (without the use of PAD) hard copy printing of the PAD output. The use of DIP files with the current CAD/CAE laboratory hardware, would require modification

to the system printer drivers in order to make the software and available printers compatible. Although this is currently undesirable, the available DIP software will be covered for future reference:

PADEXE.COM: In addition to on screen plotting, PADEXE.COM allows the input plotting data to be converted for use as:

1. Versatec (.PLV) files
2. ATI laser printer (.ATI) files
3. QMS laser printer (.QMS) files
4. Dicomed (.D48) files

LN3.COM: This command file allows direct printing of DIP file data on a DEC LN03 Plus laser printer.

DIPLN3SYS: This file contains a letter and a copy of a command file which will modify the system print queues, allowing use of a LA75 or LA 210 printer. The CAD/CAE laboratory currently has a LA210 printer hooked up to host KELLY. Modification of the system print queue to allow direct printing on the available printer would mean a higher quality of graphics resolution. Such a modification is a possibility if the modification would be limited to the use of the DIPLN command file and would not affect the normal use of the LA210 printer by other users.

DIPSLN.COM: This is the command file for using program DIPSLN.

DIPSLN.FOR: This source code allows the plotting of a DIP file on a Selanar graphics terminal using the Tektronic 4010 graphics protocol.

SUBPMARC.COM: This command procedure allows running of PMARC in the batch mode. This is a necessary feature when running some of the larger PMARC jobs. For each separate job input, SUBPMARC.COM is edited to change the logical names of the input, output and plot files.

RUNNING PMARC

PMARC is a large code which is normally run on the Cray computer by NASA Ames engineers. The CPU time per iteration for 4000 panels is .695 seconds on a Cray verses 119.145 seconds on a MicroVAX II. A test case was run on the NPS CAD/CAE MicroVAX for a 4 digit NACA wing. The run time was approximately 53 minutes.

Before the executable PMARC_10 code can be run, input, output , and plot files must be set up. In the PMARC program, data5, data6, and data7 are the logical names for the input, output, and plot files, repetitively. This is accomplished through the ASSIGN command. For the test case, the manual commands are as follows:

```
$ ASSIGN TESTA.JOB
_LOG NAME: DATA5
$ ASSIGN TESTA.OUT
_LOG NAME: DATA6
$ ASSIGN TESTA.PLT
```

_*LOG NAME:* DATA7

Care should be taken to DEASSIGN any assigned logical names after the running of PMARC to prevent interfering with other FORTRAN programs run from the same directory.

When running PMARC input files on systems other than the system on which the file was created, it is necessary to change the protection of the file to allow world access. This is accomplished through the command: $SET PROTECTION= W:RWED FN(file name).

RUNNING PMARC IN THE BATCH MODE

Batch jobs are submitted using the command procedure SUBPMARC.COM. Only three jobs will execute simultaneously on the CAD/CAE computer network. When running large jobs, that is jobs, where the geometry consists of over 1000 panels, the computer runs out of disk storage space. When submitting more than one large job the batch que at one time, it is necessary to delay the submission times of SUBPMARC.COM. This is accomplished using the input: $ SUBMIT/LOG/AFTER= XX XXX XXXX (DAY MONTH YEAR) XX:XX (HOUR:MINUTE). The "/LOG" causes a log to be printed after a job is run. This is particularly helpful when trouble shooting a particular problem, or to find out how long a job took to execute in the batch que.

When running in the batch mode, it is possible to check on the progress of jobs with the command: $ SHOW QUEUE. If a job needs to be terminated for any reason, the command is: $ DELETE/ENTRY= XXXX (the entry number from the job which is running) SYS$BATCH (the name of the default batch queue). This

delete command is the same procedure to be used for aborting a print job. The only difference is the queue name, which for printing is: SYS$PRINT.

PMARC OUTPUT

The output file from PMARC can be quite long, depending on what output items were set in the initial input deck. It is recommended that the first time PMARC user prints the output for a small job, such as the wing test case, in order to gain familiarity with the output information. It is necessary to modify the screen width in order to view all of the information written to the PMARC output file. The command used is: $ SET TERMINAL/WIDTH =130.

Familiarity with the EDT editor is a necessity in order to quickly get to the output information one is interested in. The "FIND" feature was the most expeditious way to find information. By "finding" key words in the output file which are near the required information, one can quickly move around the rather large output files. If a certain part of the output needs to be printed, there is one method which does not require printing out of the entire file: Once in the full page editing mode, it is necessary to place the cursor at the beginning of the section that is to be printed. By pressing CTRL "Z", the line editing mode is invoked. by entering "-1", the screen shows the line number of the line which is one line above where the cursor was pointing in the full page mode. After reentering the full page mode by entering "C", the cursor is placed on the line at the end of the section of interest. The procedure from above is followed, so that the beginning and ending line numbers of the section are known. While still in the line editing mode, it is possible to send the desired out put section to another file which can be printed. The following commands apply: * PRINT FN (the file name that you want to write to) XXX:YYY (beginning line number:ending line number). Now, the file that was

written to can be printed. Two items to note are: 1) if the line numbers are not desired in the printed out file, "NONUM" must be set prior to printing to the file; 2) the file written to will contain the form feed symbol, <FF>, which can be deleted in the edit mode if desired.

RUNNING PAD

The PAD program is very interactive and easy to use. The command procedure needs to be modified to set up the run directory for the PAD program. The procedure was modified on the CAD/CAE Vax network as follows: DEFINE RUNDIR WASP$DUA0 [XXXX (the directory name from which the PAD executable code is running from)]. The PAD command procedure is run by the command @PAD.COM. The printers available in the CAD/CAE laboratory are not directly compatible with the PAD program as it is currently configured. The print screen procedure had to be utilized in order to obtain hard copies of the on screen plots.

APPENDIX D
PMARC USERS GUIDE

PMARC Pre-Release Version 10.0, 3/7/89

PMARC

(Panel Method Ames Research Center)

Users Guide

Basic Input Section to Run PMARC

The basic data section of the input deck for PMARC consists of a set of namelist definitions. The required format for the basic data section is shown below. The best way to handle the basic data section is to create a template file which can then be included into any PMARC file and the values modified appropriately. All the namelists should always be included as shown below whether or not a particular namelist is needed for the job being run. If a namelist is not needed for a particular job, PMARC merely skips over that namelist. Each namelist must begin with an & and the namelist name (i.e. BINP2, BINP3, etc.) and end with &END. Blank spaces in a namelist are ignored, so the items in each namelist can be spaced in whatever fashion the user desires. A namelist can extend over as many lines as necessary. A description of each input variable and the valid input values follows. Under the Value column in the input description, the letter I means an integer value and the letter R means a real value.

NOTE: Variables in the namelist definition which are arrays should have their elements listed out following the variable name. For example, if there were three values to be entered into the array NORPCH, the input would be as follows: NORPCH = N1,N2,N3. The rest of the elements in array NORPCH will automatically be left at zero.

```
TYPE YOUR TITLE FOR THIS INPUT FILE HERE

&BINP2    LSTINP=2,  LSTOUT=0,  LSTFRQ=1,  LENRUN=0,                    &END
&BINP3    LSTGEO=0,  LSTNAB=0,  LSTWAK=0,  LSTCPV=0,  LSTJET=0, &END
&BINP4    MAXIT=75,  SOLRES=0.0005,                                     &END
&BINP5    NTSTPS=1,  DTSTEP=0.1,                                        &END
&BINP6    RSYM=0.0,  RGPR=0.0,  RFF=5.0,  RCORE=0.05,                   &END
&BINP7    VINF=1.0,  VSOUND=1116.0,    UNIT=0,   COMPOP=0.0,            &END
&BINP8    ALDEG=4.0, YAWDEG=0.0, THEDOT=0.0, PSIDOT=0.0, PHIDOT=0.0,    &END
&BINP9    CBAR=3.00, SREF=100.0, SSPAN=15.0,
          RMPX=0.00,  RMPY=0.00, RMPZ=0.00,                             &END
&BINP10   NORSET=0,  NBCHGE=0,  NCZONE=0,
          NCZPAN=0,  CZDUB=0.0, VREF=00.0,                              &END
&BINP11   NORPCH=0,
          NORF=0,          NORL=0,
          NOCF=0,          NOCL=0,
          VNORM=0.0,                                                    &END
&BINP12   KPAN=0,   KSIDE=0,   NEWNAB=0,   NEWSID=0,                    &END
&FINISH   FIN=1,                                                        &END
```

RECORD 1: Job Title

Variable	Value	Description
TEXT		Alphanumeric text identifying the job. This record is not entered in namelist format, but merely typed in anywhere on the first line of the input deck.

BINP2: Job Control

Variable	Value	Description
LSTINP		Input data print options
	0	Prints all input data except the geometry input.
	1	Prints all input data except the detailed coordinates of the geometry input.
	2	Prints all input data.
LSTOUT		Output print options
	0	Basic print of output.
	1	Allows any or all of the additional print options to be set manually on BINP3.

Variable	Value	Description
LSTFRQ		Controls frequency of printout in the time-stepping loop.
	0	Prints out detailed panel data only on last step. Force and moment data and solution iteration history printed at every step.
	1	Prints all data at every step.
	I	Prints out detailed panel data at every Ith step, including the first and last step. Force and moment data and solution iteration history printed at every step.
LENRUN	0	Complete run through code.
	2	Run through geometry only. Geometry is written to plot file.
	3	Run through geometry and wake initialization routines. Geometry and initial wake data are written to plot file.

BINP3: Additional Print Options

Variable	Value	Description
LSTGEO		Panel geometry printout options.
	0	Print option off.
	1	Panel corner points printed for all panels.
	2	Panel corner points and unit normal vectors printed for all panels.
	3	Panel corner points, unit normal vectors, and panel sets with prescribed normal velocities are printed out.

Variable	Value	Description
LSTNAB		Panel neighbor information printout options.
	0	Print option off
	1	Prints neighbor information for all panels.
LSTWAK		Wake data printout options.
	0	Print option off.
	1	Prints wake-shedding information for each wake column.
	2	Prints wake-shedding information for each wake column and wake line geometry.
	3	Prints wake-shedding information for each wake column, wake line geometry, and wake panel doublet values.
LSTCPV		Panel corner point analysis printout options.
	0	Print option off.
	1	Prints out panel corner point analysis results. Will be printed according to the LSTFRQ value selected.
LSTJET	0	Print option off
	1	Print out jet analysis results

BINP4: Solver Parameters

Variable	Value	Description
MAXIT	I	Limit on number of solver iterations (150 max)
SOLRES	R	Convergence criteria for the matrix solver. Recommended setting is 0.0005.

BINP5: Time-Step Parameters

Variable	Value	Description
NTSTPS	I	Number of wake time-steps.
DTSTEP	R	Size of the time-step (seconds).

BINP6: Symmetry and Computation Parameters

Variable	Value	Description
RSYM	0.0	Symmetrical case (about Y=0). Code computes the influence of the mirror image of the paneled geometry. The paneled geometry must lie in the +Y side of the global coordinate system and abut the Y=0 plane.
	1.0	Asymmetrical case (about Y=0). The entire geometry must be paneled. The paneled geometry may lie in +Y or -Y (or both) side of the global coordinate system.
RGPR	0.0	No ground plane modeled at Z=0.
	1.0	Ground plane modeled at Z=0.
RFF	5.0	Far-field-factor. (multiplies panel reference length to determine far-field radius for each panel).
RCORE	0.05	Core radius. Used when computing velocities near a doublet panel edge. Has units consistent with global geometry.

BINP7: Free Stream Conditions

Variable	Value	Description
VINF	1.0	Nondimensional free stream velocity. A velocity of 1.0 length unit/sec is used for the time-stepping portion of the code, where length unit is the units used for the paneled geometry.
	R	Dimensional free stream velocity (units should agree with option selected under UNIT below and with global units used for the geometry).
VSOUND	R	Dimensional speed of sound (units should agree with VINF).
UNIT	0	All velocities are nondimensional.
	1	Velocities are in (ft/sec).
	2	Velocities are in (m/sec).

Variable	Value	Description
COMPOP		Compressibility option.
	0.0	Incompressible flow.
	1.0	Prandtl-Glauert compressibility correction.

BINP8: Angular Position and Rotation Rates

Variable	Value	Description
ALDEG	R	Angle of attack in degrees.
YAWDEG	R	Yaw angle in degrees.
THEDOT	R	Rotation rate about Y axis. (deg/sec)
PSIDOT	R	Rotation rate about Z axis. (deg/sec)
PHIDOT	R	Rotation rate about X axis. (deg/sec)

BINP9: Reference Dimensions

Variable	Value	Description
CBAR	R	Reference chord used for normalizing pitching moment. (units must be consistent with units used to define geometry).
SREF	R	Reference area for force and moment coefficients. If a plane of symmetry is used, the reference area for the paneled and reflected geometry should be used. (units must be consistent with units used to define geometry).
SSPAN	R	Semispan used for normalizing rolling and yawing moments. (units must be consistent with units used to define geometry).
RMPX	R	Coordinates of the moment reference RMPY point in global coordinate system.
RMPZ		

BINP10: Special Options

Variable	Value	Description
NORSET	I	The number of groups of panels on which nonzero normal velocities are to be prescribed.
NBCHGE	I	The number of panel neighbor information changes that are to be made. Changing the neighbor information on one side of one panel constitutes one change.
NCZONE	0	Regular external flow problem.
	1	Internal flow problem
NCZPAN	I	Panel number of the panel on which the doublet value is specified for internal flow modeling.
CZDUB	R	The doublet value that is set on panel NCZPAN for internal flow modeling. A value of 0.0 is recommended unless convergence problems occur in the matrix solution.
VREF	R	The reference velocity for computing Cp in internal flow problems. If left at 0.0, then VINF will be used to compute Cp.

BINP11: Normal Velocity Specification

Variable	Value	Description
NORPCH(N)	I	Patch number of patch containing the group of panels to receive a prescribed normal velocity.
NORF(N) NORL(N)	I	Number of first and last row of panels in defined panel set. Using 0 defaults to all rows on this patch.
NOCF(N)	I	Number of first and last column of NOCL(N) panels in defined panel set. Using 0 defaults to all columns on this patch.
VNORM(N)	R	Specified normal velocity for the set of panels identified above. Positive direction is outwards from the surface.

NOTE: N goes from 1 to NORSET

BINP12: Panel Neighbor Information Change

Variable	Value	Description
KPAN(N) KSIDE(N)	I I	Panel number and the side of that panel requiring a modified neighbor.
NEWNAB(N) NEWSID(N)	I I	New neighbor and the side of that neighbor adjacent to KSIDE of KPAN. If NEWNAB is set to 0 for a particular panel, then NEWSID should be set to -KSIDE. This effectively cuts the neighbor relationship across side KSIDE.

NOTE: N goes from 1 to NBCHGE

Input Section for Surface Geometry in PMARC

The surface geometry section of the input deck for PMARC consists of a set of namelist definitions. The required format for the surface geometry input section is shown below. Each namelist must begin with an & and the namelist name (i.e. PATCH1, SECT1, etc.) and end with &END. Blank spaces in a namelist are ignored, so the items in each namelist can be spaced in whatever fashion the user desires. A namelist can extend over as many lines as necessary. A description of each input variable and the valid input values follows. Under the Value column in the input description, the letter I means an integer value and the letter R means a real value.

The only geometry input data that does not use the namelist format is the basic point coordinate input. The basic point coordinate input is handled using a free format input. One set of three coordinates separated by at least one space must appear on each line. See the sample input below.

```
&ASEM1     ASEMX=0.00,   ASEMY=0.00,  ASEMZ=0.00,
           ASCAL=1.00,   ATHET=0.00,  NODEA=5,                                &END
&ASEM2     APXX=0.00,    APYY=0.00,   APZZ=0.00,
           AHXX=0.00,    AHYY=1.00,   AHZZ=0.00,                              &END


&COMP1     COMPX=  0.0000, COMPY=  0.0000, COMPZ=  0.0000,
           CSCAL=  1.0000, CTHET=  0.0,  NODEC= 5,                            &END
&COMP2     CPXX=  0.0000, CPYY=  0.0000, CPZZ=  0.0000,
           CHXX=  0.0000, CHYY=  1.0000, CHZZ=  0.0000,                       &END


&PATCH1    IREV= 0,  IDPAT= 1,  MAKE=  0,  KCOMP= 1,  KASS= 1,                &END
TYPE PATCH NAME HERE
&PATCH2    ITYP= 1,  TNODS=  5, TNPS=  3,  TINTS= 3,  NPTTIP=  0,             &END
&SECT1     STX=  0.0000, STY=  0.0000, STZ=  0.0000, SCALE=  1.0000,
           ALF=  0.0,  THETA=  0.0,
           INMODE= 1,  TNODS= 3,  TNPS= 5,  TINTS= 3,                         &END
&SECT2     RTC=  0.0000, RMC=  0.0000, RPC=   0.3000,
           IPLANE= 1,  TNPC= 1,  TINTC= 0,                                    &END
           0.0    0.0    0.0
           1.0    0.0    0.0
           1.0    0.1    0.1
           1.1    0.2    0.3
           1.3    0.5    0.7
&BPNODE    TNODE= 3,  TNPC= 5,  TINTC= 0,                                     &END
```

Description of Input Variables

ASEM1: Assembly Coordinate System Information

Variable	Value	Description
ASEMX ASEMY ASEMZ	R R R	Origin of assembly coordinate system in global coordinates.
ASCAL	R	Assembly scale. If ASCAL < 0, then namelist ASEM2 must be included. ASCAL < 0 allows rotation of assembly about an arbitrarily defined axis (defined on ASEM2) instead of the default assembly coordinate system Y axis.
ATHET	R	Rotation angle of the assembly coordinate system about the rotation axis. The default rotation axis is the assembly coordinate system Y axis. An arbitrary axis may be specified on ASEM2 if ASCAL < 0 above. Positive rotation angle is determined by Right Hand Rule.
NODEA	0	Another assembly coordinate system to be defined after this one.
	5	This is the last assembly coordinate system to be defined.

NOTE: Up to 10 assembly coordinate systems may be defined. One ASEM1 (and ASEM2 if required) must appear in the input deck for each assembly to be defined. Each ASEM2 that is required must follow immediately after its corresponding ASEM1. The assembly coordinate systems are numbered in the order in which they are defined.

ASEM2: Assembly Coordinate System Rotation Axis Input

Variable	Value	Description
APXX APYY APZZ	R R R	Starting point for vector defining assembly coordinate system arbitrary rotation axis. (entered in assembly coordinates (i.e. prior to scaling by assembly scale factor)).
AHXX AHYY AHZZ	R R R	Ending point for vector defining assembly coordinate system arbitrary rotation axis. (entered in assembly coordinates (i.e. prior to scaling by assembly scale factor)).

COMP1: Component Coordinate System Information

Variable	Value	Description
COMPX COMPY COMPZ	R R R	Origin of component coordinate system in assembly coordinates.
CSCAL	R	Component scale. If CSCAL < 0, then namelist COMP2 must be included. CSCAL < 0 allows rotation of component about an arbitrarily defined axis (defined on COMP2) instead of the default component coordinate system Y axis.
CTHET	R	Rotation angle of the component coordinate system about the rotation axis. The default rotation axis is the component coordinate system Y axis. An arbitrary axis may be specified on COMP2 if CSCAL < 0 above. Positive rotation angle is determined by Right Hand Rule.
NODEC	0	Another component coordinate system to be defined after this one.
	5	This is the last component coordinate system to be defined.

NOTE: Up to 10 component coordinate systems may be defined. One COMP1 (and COMP2 if required) must appear in the input deck for each component to be defined. Each COMP2 that is required must follow immediately after its corresponding COMP1. The component coordinate systems are numbered in the order in which they are defined.

COMP2: Component Coordinate System Rotation Axis Input

Variable	Value	Description
CPXX CPYY CPZZ	R R R	Starting point for vector defining component coordinate system arbitrary rotation axis. (entered in component coordinates (i.e. prior to scaling by component scale factor)).
CHXX CHYY CHZZ	R R R	Ending point for vector defining component coordinate system arbitrary rotation axis. (entered in component coordinates (i.e. prior to scaling by component scale factor)).

PATCH1: Patch Information

Variable	Value	Description
IREV		Patch reversal flag (for inside out patches).
	0	Patch not reversed.
	-1	Patch reversed.
IDPAT		Patch type.
	1	Wing type patch. Section force and moment data printed out.
	2	Body type patch. No section data printed.
	3	Neumann patch. (Vortex lattice sheet).
	4	Jet plume patch. (Computed by Adler/Baron code). This option requires JET1 namelist to follow PATCH1. Then a single SECT1 namelist follows (along with necessary basic point coordinates and BPNODE namelists) to define the perimeter of the jet exit with the following restriction: Only half of the jet exit is modeled. This means that the jet exit must be axisymmetric. The jet exit section definition (basic point input) must proceed in a counterclockwise direction when looking towards the jet exit. See Figure xx. The values of INMODE on SECT1 are limited to between 1 and 4, inclusive, for the jet plume patch.

Variable	Value	Description
MAKE	0	Normal patch input (namelist SECT1 must follow).
	+I	Automatic tip patch generated for side 3 of patch I. (namelist PATCH2 must follow).
	- I	Automatic tip patch generated for side 1 of patch I. (namelist PATCH2 must follow).
KCOMP	I	Number of component coordinate system to which this patch belongs. Component coordinate systems are numbered sequentially as discussed in NOTE above on COMP1. If 0 is entered, KCOMP defaults to 1.
KASS	I	Number of assembly coordinate system to which this patch belongs. Assembly coordinate systems are numbered sequentially as discussed in NOTE above on ASEM1. If 0 is entered, KASS defaults to 1. Neighbor relationships are cut between patches on different assemblies.

RECORD to be inserted after PATCH1 namelist.

Variable	Value	Description
PNAME col(1-24) (A24)	Text	Patch name

PATCH2: Automatic Tip Patch Generation Information (needed only if MAKE ≠ 0 on PATCH1)

Variable	Value	Description
ITYP		Tip patch type
	1	Flat tip patch
TNODS	3	More patches to follow this one.
	5	Last patch in the surface geometry input.
TNPS	I	Number of panels to be generated "across" the open tip. See Figure xx.
	NOTE:	The tip patch paneling will match the edge paneling of the patch to which the tip patch is being fitted.
TINTS	0	Full cosine spacing of panels "across" the open tip, with smaller panels near outer perimeter of the tip patch.
	1	Half cosine spacing of panels with smaller panels near the "begining" of the tip patch. See Figure xx.
	2	Half cosine spacing of panels with smaller panels near the "end" of the tip patch. See Figure xx.
	3	Equal spacing of panels "across" the open tip.
NPTTIP	0	This variable is not currently in use.
	NOTE:	This namelist completes the input required for this patch.

SECT1: Section Coordinate System Information

Variable	Value	Description
STX	R	Origin of section coordinate system in component coordinates.
STY	R	
STZ	R	
SCALE	R	Section scale
ALF	R	Rotation angle of the section coordinate system about its Y axis. A positive rotation angle is defined by the Right Hand Rule.
THETA	R	Rotation angle of the section coordinate system about its Z axis. A positive rotation angle is defined by the Right Hand Rule.

Variable	Value	Description
INMODE	0	Copies section definition of previous section.
	1	Input Y, Z, ΔX coordinates to define section. The X coordinate is defaulted to 0.0, but local deviations can be entered in ΔX. (basic point coordinates and BPNODE namelists follow this namelist as needed).
	2	Input X, Z, ΔY coordinates to define section. The Y coordinate is defaulted to 0.0, but local deviations can be entered in ΔY. (basic point coordinates and BPNODE namelists follow this namelist as needed).
	3	Input X, Y, ΔZ coordinates to define section. The Z coordinate is defaulted to 0.0, but local deviations can be entered in ΔZ. (basic point coordinates and BPNODE namelists follow this namelist as needed).
	4	Input X, Y, Z coordinates to define section. (basic point coordinates and BPNODE namelists follow this namelist as needed).
	5	Generate a NACA 4 digit airfoil section. (SECT2 namelist must follow this namelist).
	7	Input R, θ, X coordinates to define section. R is measured perpendicular to the section X axis and θ is measured from the section +Y axis with the positive angular direction defined by the Right Hand Rule. (basic point coordinates and BPNODE namelists follow this namelist as needed).

Variable	Value	Description
TNODS	0	First or intermediate section of patch.
	1	Break point on patch with continuous slope into the next region of patch.
	2	Break point on patch with discontinuous slope into the next region of patch.
	3	Last section definition on this patch.
	5	Last section definition on last patch of surface geometry.
TNPS	I	Number of panels to be generated between this break point and the previous break point (or the first section of this patch if this is the first or only break point). If TNPS = 0 at a break point, the input sections between this break point and the previous one will be used to define the panel edges.
TINTS	0	Full cosine spacing of panels between this break point and the previous one, with smaller panels near the two break points.
	1	Half cosine spacing of panels between this break point and the previous one, with smaller panels near the previous break point.
	2	Half cosine spacing of panels between this break point and the previous one, with smaller panels near this break point.
	3	Equal spacing of panels between this break point and the previous break point.

SECT2: NACA 4 digit airfoil section generation information (needed only if INMODE = 5 on SECT1)

Variable	Value	Description
RTC	R	The thickness to chord ratio for the airfoil.
RMC	R	The maximum chamber to chord ratio for the airfoil.
RPC	R	The chordwise position of the maximum chamber (expressed as a ratio to chord).
IPLANE		The plane in the section coordinate system used to generate the airfoil coordinates.
	1	The YZ plane.
	2	The XZ plane.
	3	The XY plane.
TNPC	I	The number of panels to be distributed between the trailing edge and the leading edge of the airfoil. The same number of panels are distributed on the upper and lower surfaces.

Variable	Value	Description
TINTC		The type of panel spacing to be used on the upper and lower surfaces of the airfoil.
	0	Full cosine spacing with smaller panels near the leading and trailing edges.(This is the recommended spacing).
	1	Half cosine spacing with smaller panels near the trailing edge.
	2	Half cosine spacing with smaller panels near the leading edge.
	3	Equal spacing.

RECORD : Section Basic Point Coordinate Input (This record is repeated for each basic point defining this section)

Variable	Value	Description
B1	R	Basic point coordinates for section definition
B2	R	The values that go in B1, B2, B3 depend
B3	R	on the value of INMODE on SECT1.

NOTE: The values of B1, B2, B3 are entered as triplets in free format, with at least one space separating each value. One triplet is entered per line.

BPNODE: Break Point Input (inserted between basic point coordinates on a section definition as needed. Must terminate basic point input for a section with a BPNODE namelist)

Variable	Value	Description
TNODE	0	First or intermediate point (i.e. not a break point. Values entered for TNPC and TINTC are ignored).
	1	Break point with continuous slope into the next region on this section.
	2	Break point with discontinuous slope into the next region on this section.
	3	Final break point. End of this section definition.
TNPC	I	Number of panels to be generated between this break point and the previous one (or the first point of the section definition if this is the first or only break point). If TNPC = 0 at a break point, the input points will be used as the panel corner points between this break point and the previous one.
	NOTE:	The total number of panels to be generated on each section of a given patch must be the same.

Variable	Value	Description
TINTC	0	Full cosine spacing of panels between this break point and the previous one, with smaller panels near the two break points.
	1	Half cosine spacing of panels between this break point and the previous one, with smaller panels near the previous break point.
	2	Half cosine spacing of panels between this break point and the previous one, with smaller panels near this break point.
	3	Equal spacing of panels between this break point and the previous break point.

JET1: Jet Plume Generation Information (needed only if IDPAT=4 on PATCH1).

Variable	Value	Description
VJET	R	The jet exit velocity. Units must be consistent with VINF.
NJDS	I	The number of jet diameters the jet plume is to be extended downstream.
DZ0	R	The step size (in jet diameters or fraction of a jet diameter) for moving down the jet plume and computing the jet parameters.
JETIN	I	The number of the panel set with prescribed normal velocity (i.e. panel set #1, #2, #3, etc. under the NORSET option in the basic data input) which corresponds to the inlet for this jet. If there is no inlet for this jet, just enter 0.
	NOTE:	The minimum number of columns of panels that will be computed for the jet plume patch can be estimated as: NJDS/DZ0 + 1 There is currently a limit of 50 columns of panels that can be computed for the jet plume patch. Thus NJDS and DZ0 must be set with this limit in mind.

Input Section for Time-stepping Wakes in PMARC

The wake geometry section of the input deck for PMARC consists of a set of namelist definitions. The required format for the wake geometry input section is shown below. Each namelist must begin with an & and the namelist name (i.e. WAKE1, SECT1, etc.) and end with &END. Blank spaces in a namelist are ignored, so the items in each namelist can be spaced in whatever fashion the user desires. A namelist can extend over as many lines as necessary. A description of each input variable and the valid input values follows. Under the Value column in the input description, the letter I means an integer value and the letter R means a real value.

The only wake input data that does not use the namelist format is the basic point coordinate input. The basic point coordinate input is handled using a free format input. One set of three coordinates separated by at least one space must appear on each line. See the sample input below.

```
&WAKE1    IDWAK=1,   IFLXW=0,                                          &END
 TYPE WAKE NAME HERE
&WAKE2    KWPACH=1,   KWSIDE=2,   KWLINE=0,   KWPAN1=0,
          KWPAN2=0,   NODEW=5,    INITIAL=1,                           &END
&SECT1    STX=  0.0000, STY=  0.0000, STZ=  0.0000, SCALE=  1.0000,
          ALF= 0.0, THETA= 0.0,
          INMODE= 4,  TNODS= 3,  TNPS= 10,  TINTS= 3,                  &END
          0.0    0.0    0.0
          0.0    1.0    0.0
          0.0    2.0    0.0
          0.0    5.0    0.0
&BPNODE   TNODE= 3,  TNPC= 10,  TINTC= 3,                              &END
```

Description of input variables

WAKE1: Wake Identification

Variable	Value	Description
IDWAK		Wake type
	0	No wakes
	1	Regular wake
IFLXW	0	Flexible wake. Wake will be time-stepped with the local velocity.
	1	Rigid wake. Wake will be time-stepped with the free-stream velocity only.

RECORD: Wake Name (record to be inserted immediately following WAKE1 namelist).

Variable	Value	Description
WNAME col(1-24) (6A4)		Text identifying the wake

WAKE2: Wake Separation Line Information

Variable	Value	Description
KWPACH	I	Surface geometry patch number that this wake separates from.
KWSIDE	I	Side of the patch which is parallel to separation line. Separation line will be in same "direction" as the patch side specified.
KWLINE	I	Row or column number within patch from which the wake separates. The edge of the row or column KWLINE from which the wake separates will be KWSIDE. If I=0, separation is from patch edge.
KWPAN1	I	Number of first panel on row or column from which wake separates (numbered locally on row or column, i.e. the first panel on the row or column is 1, the second is 2, etc.). I=0 defaults to the first panel on the row or column.
KWPAN2	I	Number of last panel on row or column from which wake separates (numbered locally on row or column). I=0 defaults to the last panel on the row or column.
NODEW	3	Indicates another wake definition is to follow after this one.
	5	Indicates this is the last wake to be defined in the wake input section.

Variable	Value	Description
INITIAL	0	No initial wake geometry to be specified.
	1	Initial wake geometry to be specified. (SECT1 namelist must follow this namelist).

SECT1: Section Coordinate System Information

Variable	Value	Description
STX	R	Origin of section coordinate system in global coordinates.
STY	R	
STZ	R	
SCALE	R	Section scale
ALF	R	Rotation angle of the section coordinate system about its Y axis. A positive rotation angle is defined by the Right Hand Rule.
THETA	R	Rotation angle of the section coordinate system about its Z axis. A positive rotation angle is defined by the Right Hand Rule.

Variable	Value	Description
INMODE	-1	Copies section definition of previous section and the values entered for STX, STY, and STZ on this section are displacement coordinates from the origin of the previous section.
	0	Copies section definition of previous section.
	1	Input Y, Z, ΔX coordinates to define section. The X coordinate is defaulted to 0.0, but local deviations can be entered in ΔX. (basic point coordinates and BPNODE namelists follow this namelist as needed).
	2	Input X, Z, ΔY coordinates to define section. The Y coordinate is defaulted to 0.0, but local deviations can be entered in ΔY. (basic point coordinates and BPNODE namelists follow this namelist as needed).
	3	Input X, Y, ΔZ coordinates to define section. The Z coordinate is defaulted to 0.0, but local deviations can be entered in ΔZ. (basic point coordinates and BPNODE namelists follow this namelist as needed).
	4	Input X, Y, Z coordinates to define section. (basic point coordinates and BPNODE namelists follow this namelist as needed).

Variable	Value	Description
TNODS	0	First or intermediate section of wake.
	1	Break point on wake with continuous slope into the next region of wake.
	2	Break point on wake with discontinuous slope into the next region of wake.
	3	Last section definition on this wake.
TNPS	I	Number of panels to be generated between this break point and the previous break point (or the first section of this wake if this is the first or only break point). If TNPS = 0 at a break point, the input sections between this break point and the previous one will be used to define the panel edges.
TINTS	0	Full cosine spacing of panels between this break point and the previous one, with smaller panels near the two break points.
	1	Half cosine spacing of panels between this break point and the previous one, with smaller panels near the previous break point.
	2	Half cosine spacing of panels between this break point and the previous one, with smaller panels near this break point.
	3	Equal spacing of panels between this break point and the previous break point.

RECORD : Section Basic Point Coordinate Input (This record is repeated for each basic point defining this section)

Variable	Value	Description
B1	R	Basic point coordinates for section definition
B2	R	The values that go in B1, B2, B3 depend
B3	R	on the value of INMODE on SECT1.

NOTE: The values of B1, B2, B3 are entered as triplets in free format, with at least one space separating each value. One triplet is entered per line.

BPNODE: Break Point Input (inserted between basic point coordinates on a section definition as needed. Must terminate basic point input for a section with a BPNODE namelist)

Variable	Value	Description
TNODE	0	First or intermediate point (i.e. not a break point. Values entered for TNPC and TINTC are ignored).
	1	Break point with continuous slope into the next region on this section.
	2	Break point with discontinuous slope into the next region on this section.
	3	Final break point. End of this section definition.
TNPC	I	Number of panels to be generated between this break point and the previous one (or the first point of the section definition if this is the first or only break point). If TNPC = 0 at a break point, the input points will be used as the panel corner points between this break point and the previous one.
	NOTE:	The total number of panels to be generated on each section of this wake must be the same as the total number of surface geometry panels that this wake separates from.

Variable	Value	Description
TINTC	0	Full cosine spacing of panels between this break point and the previous one, with smaller panels near the two break points.
	1	Half cosine spacing of panels between this break point and the previous one, with smaller panels near the previous break point.
	2	Half cosine spacing of panels between this break point and the previous one, with smaller panels near this break point.
	3	Equal spacing of panels between this break point and the previous break point.

Input Section for Special Options in PMARC

Onbody streamlines and boundary layer analysis are not currently functional in PMARC because these routines are in the process of being replaced.

Off-body velocity scan input section

Description of Input Variables

The off-body velocity scan input data follows immediately after the end of the wake input section. The off-body velocity scan input section of PMARC consists of a set of namelist definitions. The required format for the velocity scan input section is shown below. The best way to handle the velocity scan input section is to create a template file which can then be included into any PMARC file and the values modified appropriately. All the namelists should always be included as shown below whether or not a particular namelist is needed for the job being run. If a namelist is not needed for a particular job, PMARC merely skips over that namelist. Each namelist must begin with an & and the namelist name (i.e. VS1, VS2, etc.) and end with &END. Blank spaces in a namelist are ignored, so items in each namelist can be spaced in whatever fashion the user desires. A namelist can extend over as many lines as necessary. A description of each input variable and the valid input values follows. Under the Value column in the input description, the letter I means an integer value and the letter R means a real value.

NOTE: Variables in the namelist definition which are arrays should have their elements listed out following the variable name. For example, if there were three values to be entered into the array X0, the input would be as follows: X0 = R1,R2,R3. The rest of the elements in array X0 will automatically be left at zero.

```
&VS1     NVOLR= 1,    NVOLC= 1,                                          &END
&VS2     X0=   -2.0000, Y0=    0.0000, Z0=   -2.0000,                     &END
&VS3     X1=    2.0000, Y1=    0.0000, Z1=   -2.0000, NPT1= 20,           &END
&VS4     X2=   -2.0000, Y2=    0.0000, Z2=   -2.0000, NPT2=  0,           &END
&VS5     X3=   -2.0000, Y3=    0.0000, Z3=    2.0000, NPT3= 40,           &END

&VS6     XR0=   0.0000, YR0=   0.0000, ZR0=   0.0000,                     &END
&VS7     XR1=   0.0000, YR1=  10.0000, ZR1=   0.0000,
         XR2=   0.0000, YR2=   0.0000, ZR2=   1.0000,                     &END
&VS8     R1=    0.5000, R2=    5.0000, PHI1=  0.0,    PHI2=330.0,         &END
&VS9     NRAD= 10,    NPHI= 12,    NLEN= 5,                               &END
&LAST    FINISH=1,                                                        &END
```

VS1:

Variable	Value	Description
NVOLR	I	Number of rectangular scan volumes
NVOLC	I	Number of cylindrical scan volumes

VS2:

Variable	Value	Description
X0(N) Y0(N) Z0(N)	R R R	Coordinates of origin of scan volume N See Figure xx.

VS3:

Variable	Value	Description
X1(N) Y1(N) Z1(N)	R R R	Coordinates of corner in i direction for scan volume N. See Figure xx.
NPT1(N)	I	Number of scan points to be distributed along side i of scan volume N.

VS4:

Variable	Value	Description
X2(N) Y2(N) Z2(N)	R R R	Coordinates of corner in j direction for scan volume N. See Figure xx.
NPT2(N)	I	Number of scan points to be distributed along side j of scan volume N.

VS5:

Variable	Value	Description
X3(N) Y3(N) Z3(N)	R R R	Coordinates of corner in **k** direction for scan volume N. See Figure xx.
NPT3(N)	I	Number of scan points to be distributed along side **k** of scan volume N.

NOTE: N goes from 1 to NVOLR

VS6:

Variable	Value	Description
XR0(N) YR0(N) ZR0(N)	R R R	Coordinates of origin of cylindrical scan volume N. See Figure xx.

VS7:

Variable	Value	Description
XR1(N) YR1(N) ZR1(N)	R R R	Coordinates of point defining axis (from XR0, YR0, ZR0) of cylindrical scan volume N. (Cannot be XR0, YR0, ZR0). See Figure xx.
XR2(N) YR2(N) ZR2(N)	R R R	Coordinates of point defining vector (from XR0, YR0, ZR0) from which PHI is measured for scan volume N. See Figure xx.

VS8:

Variable	Value	Description
R1(N)	R	Inner radius of cylindrical scan volume N.
R2(N)	R	Outer radius of cylindrical scan volume N.
PHI1(N)	R	Starting angle (measured from the vector (XR2-XR0),(YR2-YR0), (ZR2-ZR0)) for cylindrical scan volume N.
PHI2(N)	R	Ending angle (measured from the vector (XR2-XR0),(YR2-YR0), (ZR2-ZR0)) for cylindrical scan volume N.

VS8:

Variable	Value	Description
NRAD(N)	I	Number of points to be distributed in the radial direction for cylindrical scan volume N.
NPHI(N)	I	Number of points to be distributed in the ϕ direction for cylindrical scan volume N.
NLEN(N)	I	Number of points to be distributed in the axial direction for cylindrical scan volume N.

NOTE: N goes from 1 to NVOLC

Off-body streamline input section

Description of Input Variables

The off-body streamline input data must follow immediately after the off-body velocity scan data. The off-body streamline input section of PMARC consists of a namelist which defines the number of streamlines there will be for the job and a namelist definition which is repeated for each separate streamline. The required format for the off-body streamline input section is shown below. The best way to handle the off-body streamline input section is to create a template file with a single streamline which can then be included into any PMARC file and the values modified appropriately. Both of the namelists shown below should always be included in the input deck, whether or not there will be any off-body streamlines. If a namelist is not needed for a particular job, PMARC merely skips over that namelist. Each namelist must begin with an & and the namelist name (i.e. SLIN1, SLIN2, etc.) and end with &END. Blank spaces in a namelist are ignored, so the items in each namelist can be spaced in whatever fashion the user desires. A namelist can extend over as many lines as necessary. A description of each input variable and the valid input values follows. Under the Value column in the input description, the letter I means an integer value and the letter R means a real value.

```
&SLIN1    NSTLIN=1,                                               &END
&SLIN2    SX0=  -3.0000, SY0=   0.0000, SZ0=   0.0500,
          SU=   0.0000, SD=   6.5000, DS=   0.0250,                &END
```

SLIN1:

Variable	Value	Description
NSTLIN	I	Number of streamlines to be defined.

SLIN2:

Variable	Value	Description
SX0	R	Global coordinates for starting point of SY0
	R	streamline.
SZ0	R	
SU	R	Distance streamline to be traced in upstream direction (same units of length as geometry).
SD	R	Distance streamline to be traced in downstream direction (same units of length as geometry).
DS	R	Step size to be used in tracing streamline (Δ distance)

NOTE: Record SLIN2 must be repeated NSTLIN times (one for each streamline).

APPENDIX E
GEOMETRY PANELING INFORMATION

The intent of the information presented in this appendix is not to be a complete guide to geometry paneling, but rather to supplement the information presented in the VSAERO Users Guide [Ref. 11] and the PMARC Users Guide [Appendix D].

The geometry input can be in any dimensions or non-dimensional. The various PMARC jobs for PIONEER were input in terms of the main wing chord, using the leading edge of the main wing as the origin of the entire aircraft geometry. The automatic wing generating capability of PMARC, INMODE= 5, was used to generate the NACA 4415 wing section (Figure E.1). By altering the position or rotation of the end of the wing section (see Appendix F), one can rather simply twist the wing, add incidence to the wing root, sweep it, increase the length, shorten the length, add dihedral or anhedral, or even taper the wing (by scaling the section).

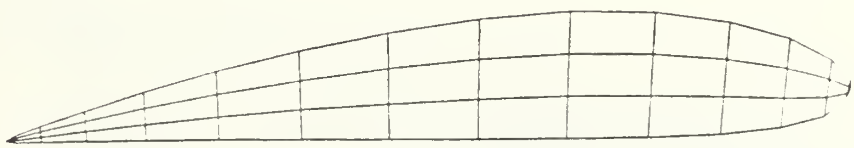


Figure E.1. NACA 4415 Wing Section

The PIONEER geometry was developed in sections. After the wing was generated, the fuselage was built up. The following figures, Figures E.2 - E.7, show the geometry of PIONEER in the order that it was input into the final geometry input (Appendix G).

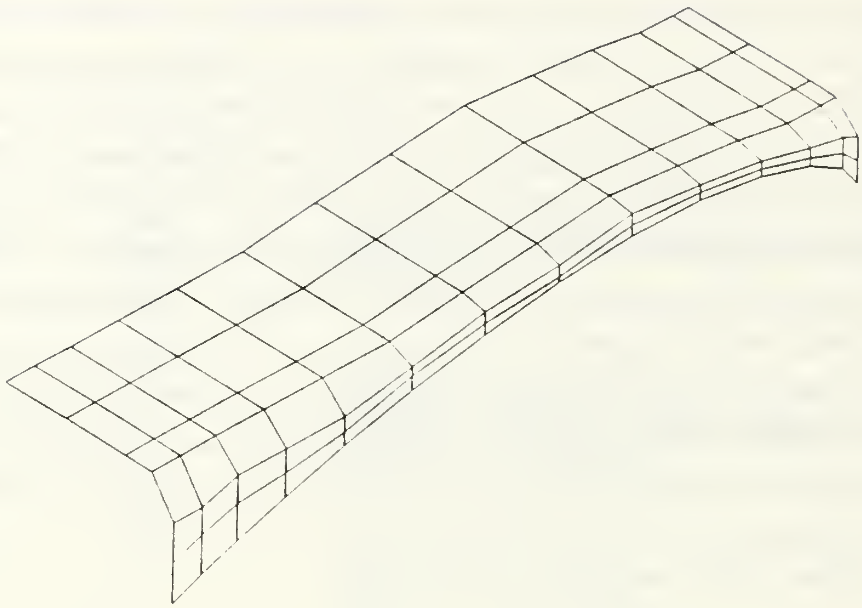


Figure E.2. PIONEER Fuselage Top

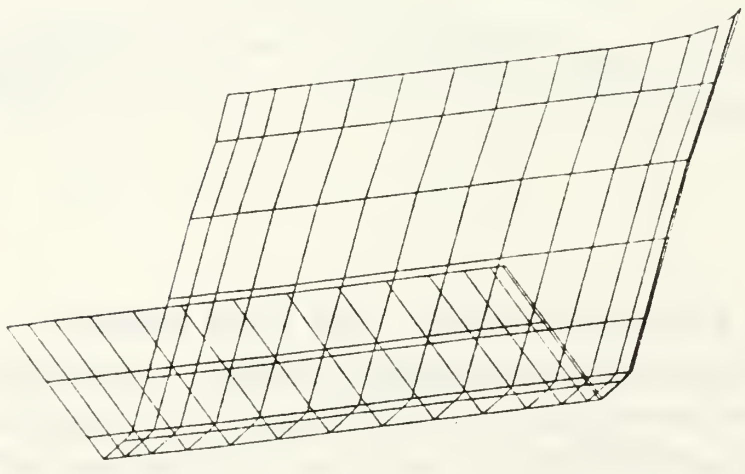


Figure E.3. PIONEER Fuselage Bottom

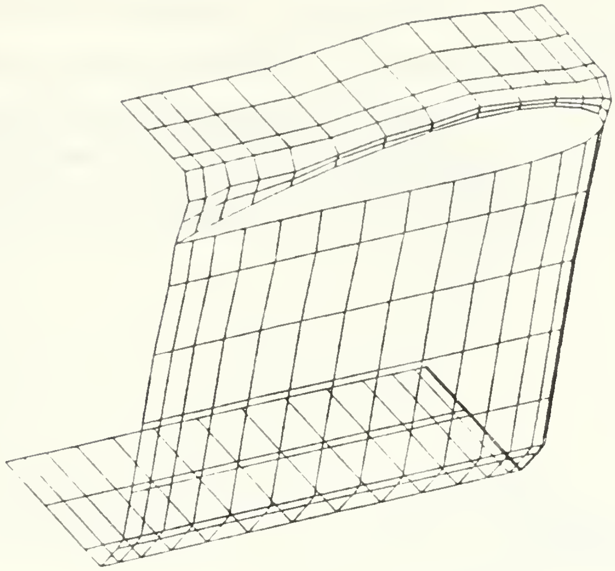


Figure E.4. PIONEER Fuselage Top and Bottom

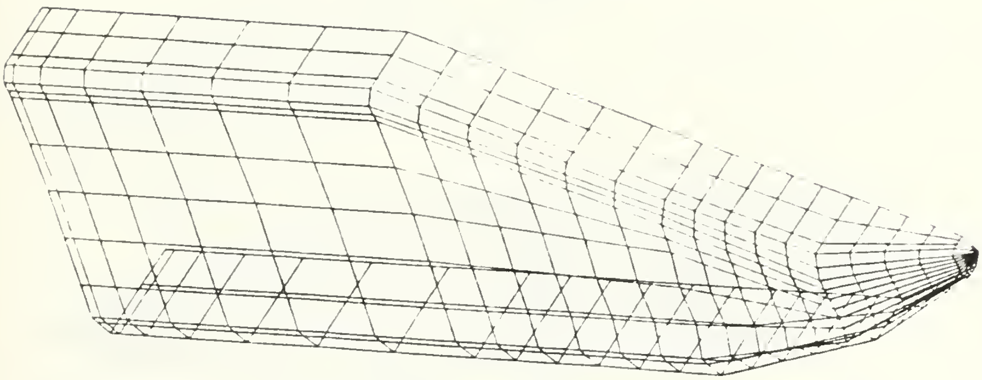


Figure E.5. PIONEER Fuselage Forward

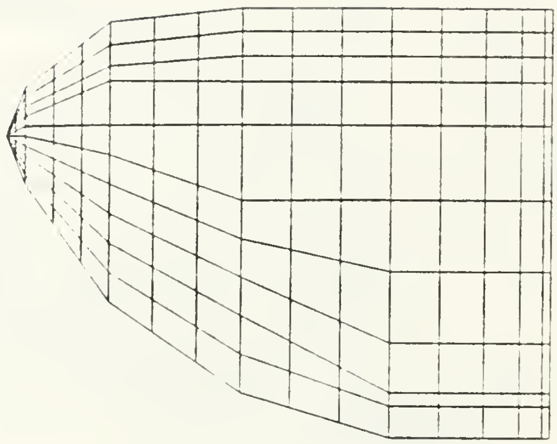


Figure E.6. PIONEER Fuselage Rear

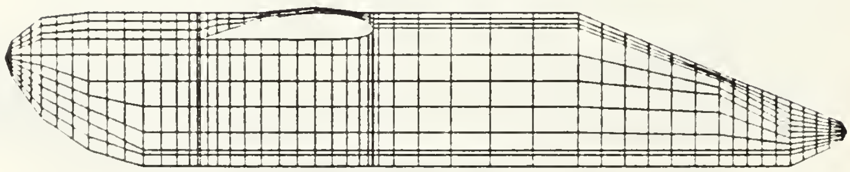


Figure E.7. PIONEER Fuselage

The PIONEER geometry had various joints between aircraft components which required many patches to ensure an exact fit. The geometry as it was input to PMARC is the first attempt to panel PIONEER. Future models of PIONEER should strive for a more efficient use of panels in the input geometry. The panel corner points from the automatic wing section generation (found in the output file) were used for some of the wing-boom junction points which were input manually (Figure E.9).

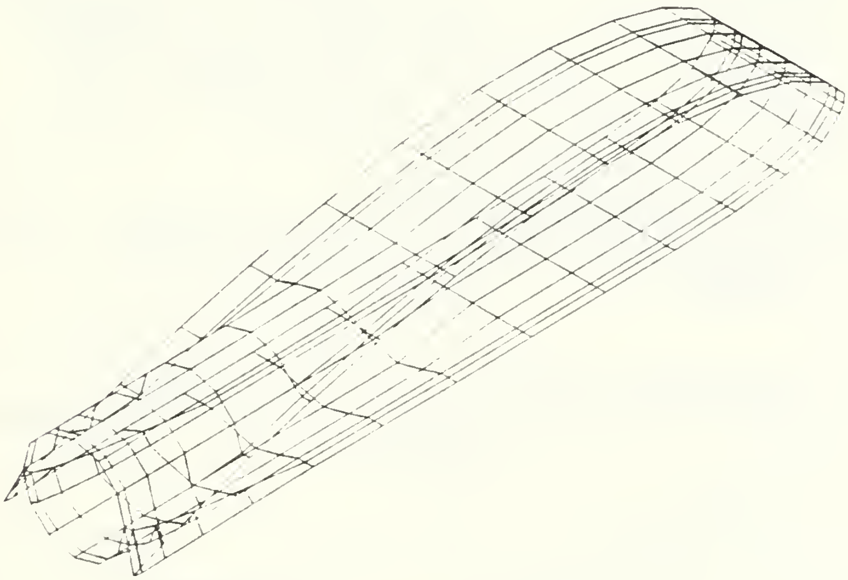


Figure E.8. PIONEER Main Wing-Boom Junction

The tail sections of both the large and small tail configurations of PIONEER proved to be the most tedious to panel due to the number of intersections at the tail surfaces. The geometry was further complicated by the 10° rotation of the vertical tail surfaces. The geometry points for the tail inputs were obtained from running preliminary geometries, so that the proper panel corner points could be obtained. PMARC allows geometries to be rotated about arbitrary lines, which are specified in the input deck. The canted vertical tail surface points were obtained by generating a

NACA 0012 wing section, copying the section to the appropriate span length, and rotating the tail 10° about the junction of the vertical and horizontal tail. The forward section of the junction was left open, so that the boom could be fitted (Figure E.9). The components placed together comprise a half-plane model of PIONEER (Figure E.10).

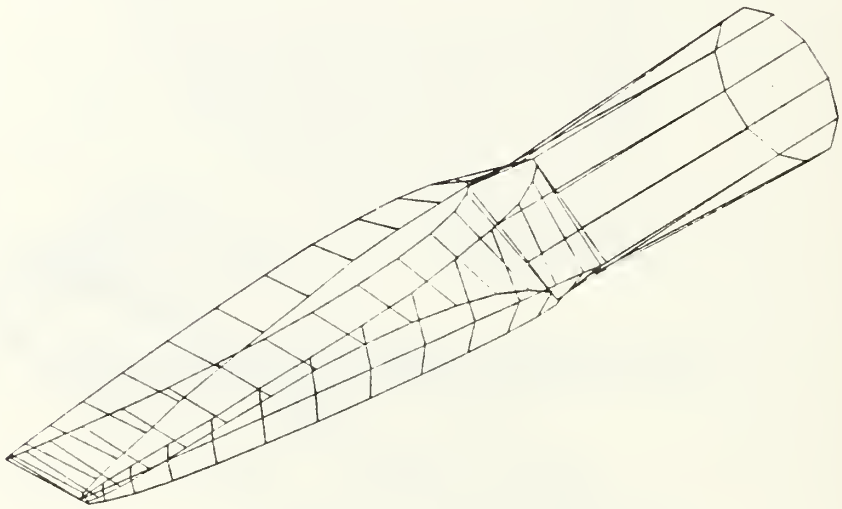


Figure E.9. PIONEER (small tail) - Horizontal Tail/Vertical Tail/Boom Junction

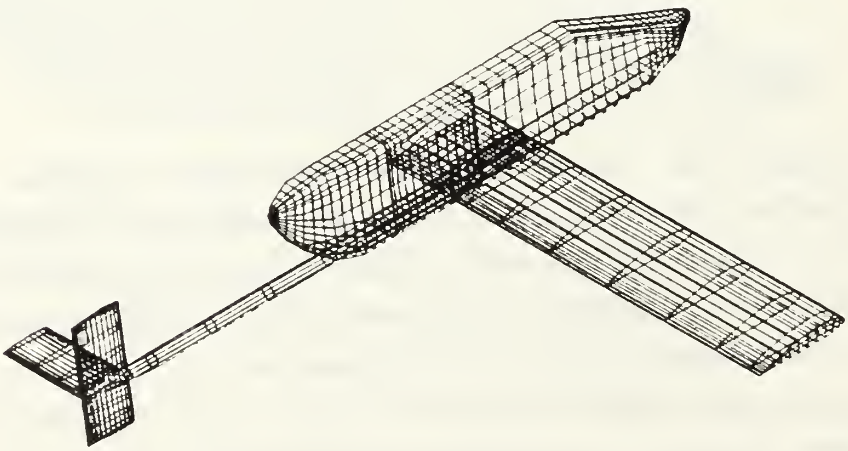


Figure E.10. PIONEER (small tail)

The large tail geometry had the same basic geometry inputs for the vertical tail and horizontal tail junctions (Figure E.11)with the difference from the small tail geometry being that the boom connects to the horizontal tail (Figure E.12).

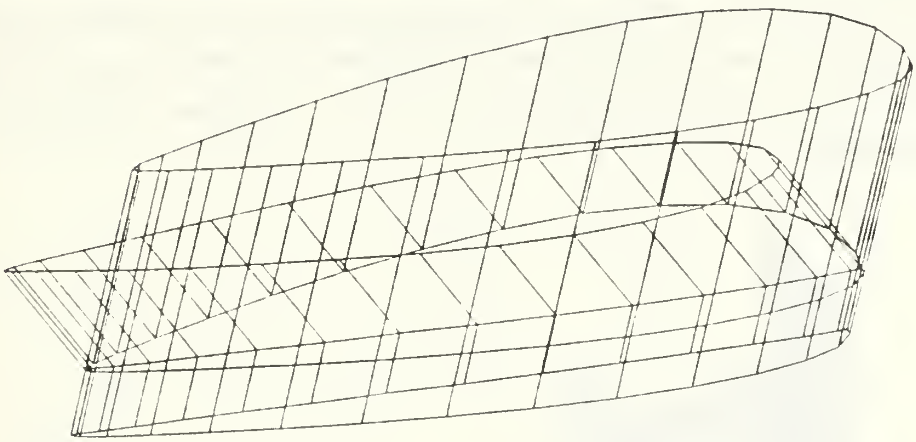


Figure E.11. PIONEER (large tail) - Horizontal Tail/Vertical Tail Junction

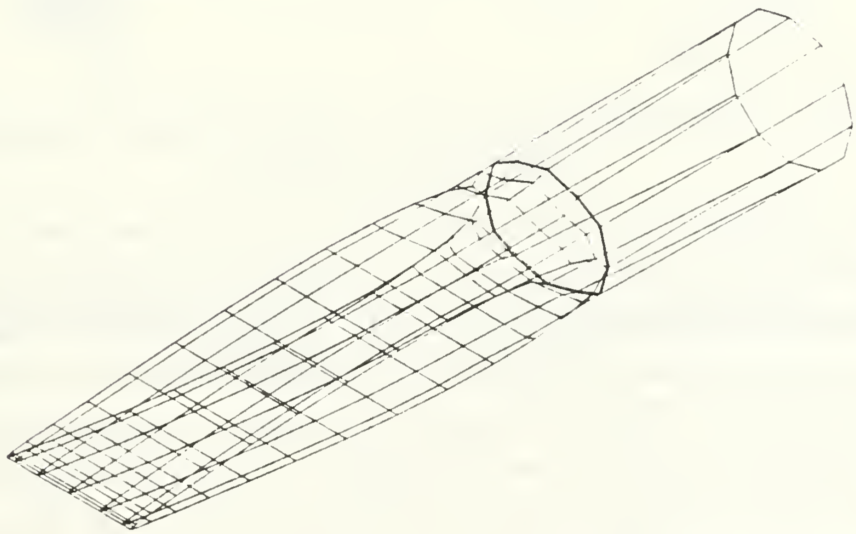


Figure E.12. PIONEER (large tail) - Horizontal Tail/Boom Junction

The geometry inputs for these sections were further complicated by the modeling of control inputs. The geometry panel corner points for the deflected surfaces was handily obtained by rotating the entire geometry about the control surface hinge line. The points for the "deflected" surface were taken from the output file. The points for the normal, undeflected geometry were input into PMARC up to the hinge line of the control surface, at which time, the points for the deflected surface were input. Thus, a complicated geometry with control deflections could be modeled (Figure E.13)

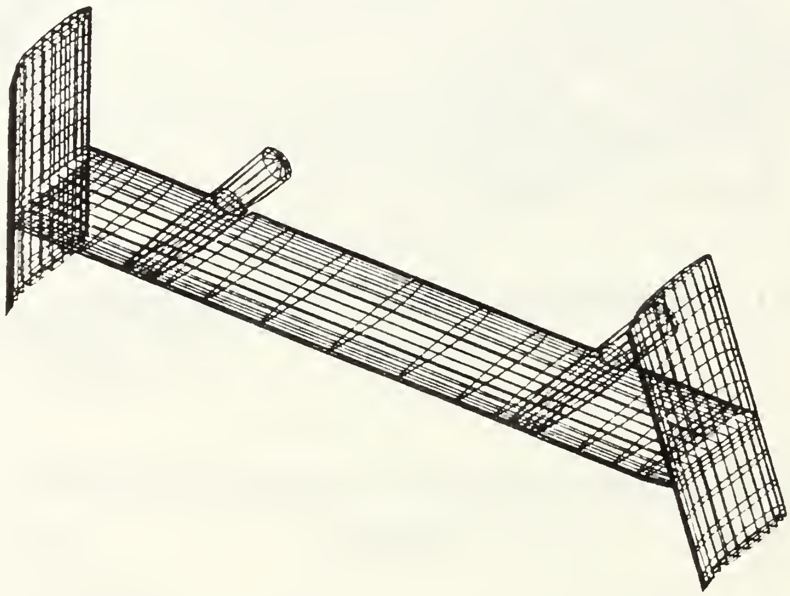


Figure E.13. PIONEER (large tail) - Horizontal Tail/Vertical Tail With 20° Rudder Deflection

When running PMARC for non-symmetrical cases, it is necessary to panel the entire geometry. The negative geometry was obtained by copying the positive input geometry and placing a negative in front of all "Y" values. When this method is used, it must be noted that the input order of the panels is reversed, which will turn the patches inside out. This was overcome by reversing the patches with "IREV" set to "-1" in the input deck for the particular section. Care should be taken when placing the minus signs in the input. One minus sign in a 20 page input can alter the geometry input radically (Figure E.14).

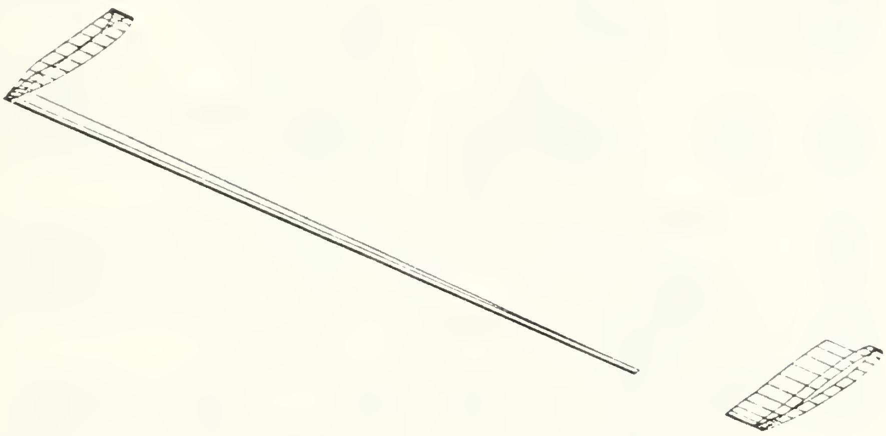


Figure E.14. PIONEER (large tail) - Horizontal Tail/Vertical Tail Junction (partial geometry)

APPENDIX F
PMARC INPUT DATA FOR NACA 4415 WING

```
NACA 4415, ASPECT RATIO = 9.1
&BINP2   LSTINP=2,    LSTOUT=1,    LSTFRQ=0,    LENRUN=0,                    &END
&BINP3   LSTGEO=0,    LSTNAB=0,    LSTWAK=0,    LSTCPV=0,    LSTJET=0,       &END
&BINP4   MAXIT=75,    SOLRES=0.0005,                                         &END
&BINP5   NTSTPS=1,    DTSTEP=0.5,                                            &END
&BINP6   RSYM=1.0,    RGPR=0.0,    RFF=5.0,    RCORE=0.05,                   &END
&BINP7   VINF=1.00,   VSOUND=1116.0,           UNIT=0,     COMPOP=0.0,       &END
&BINP8   ALDEG=4.0,  YAWDEG=0.0,  THEDOT=0.0,  PSIDOT=0.0,  PHIDOT=0.0,      &END
&BINP9   CBAR=1.0,    SREF=9.10,   SSPAN=4.55,
         RMPX=0.33,   RMPY=0.00,   RMPZ=0.00,                                &END
&BINP10  NORSET=0,    NBCHGE=0,    NCZONE=0,
         NCZPAN=0,    CZDUB=0.0,   VREF=0.0,                                 &END
&BINP11  NORPCH=0,    NORF=0,      NORL=0,
         NOCP=0,      NOCL=0,      VNORM=0.0,                                &END
&BINP12  KPAN=0,      KSIDE=0,     NEWNAB=0,    NEWSID=0,                    &END

&ASEM1   ASEMX=0.00,      ASEMY=0.00,      ASEMZ=0.00,
         ASCAL=1.00,      ATHET=0.00,      NODEA=5,                          &END
&ASEM2   APXX=0.00,       APYY=0.00,       APZZ=0.00,
         AHXX=0.00,       AHYY=1.00,       AHZZ=0.00,                        &END

&COMP1   COMPX= 0.0000,    COMPY= 0.0000,    COMPZ= 0.0000,
         CSCAL=  1.000   , CTHET=   0.0,     NODEC= 5,                       &END
&COMP2   CPXX= 0.0000,     CPYY= 0.0000,     CPZZ= 0.0000,
         CHXX= 0.0000,     CHYY=  1.000   ,  CHZZ= 0.0000,                   &END

&PATCH1  IREV=  0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,        &END
          WING
&SECT1   STX=    0.0000, STY= 0.0,    STZ= 0.0000,    SCALE=  1.000    ,
         ALF=   3.0,  THETA=   0.0,
         INMODE=  5,  TNODS= 0,    TNPS=  0,    TINTS= 0,                    &END
&SECT2   RTC=    0.1500, RMC= 0.0400,    RPC= 0.4000,
         IPLANE=  2,  TNPC= 15,    TINTC= 0,                                 &END
&SECT1   STX=    0.0000, STY=4.3,    STZ= 0.0000,    SCALE=  1.000    ,
         ALF=   3.0,  THETA=   0.0,
         INMODE=  0,  TNODS= 3,    TNPS= 12,    TINTS= 0,                    &END

&PATCH1  IREV=  0,    IDPAT= 1,    MAKE=   1,   KCOMP= 1,    KASS= 1,        &END
          WING TIP
&PATCH2  ITYP=  1,    TNODS= 3,    TNPS=   3,   TINTS= 3,    NPTTIP=0,       &END

&WAKE1   IDWAK=1,         IPLXW=0,                                           &END
 WING WAKE INNER
&WAKE2   KWPACH=1,        KWSIDE=2,       KWLINE=0,       KWPAN1=0,
         KWPAN2=0,        NODEW=3,        INITIAL=1,                         &END
&SECT1   STX=   10.000, STY=     0.0, STZ=     0.0, SCALE=    1.0000,
         ALF=   0.0,  THETA=   0.0,
         INMODE= -1,  TNODS= 3,    TNPS= 10,    TINTS= 1,                    &END

&VS1     NVOLR= 0,        NVOLC= 0,                                          &END
&VS2     X0=     -2.0000, Y0=      0.0000, Z0=     -2.0000,                  &END
&VS3     X1=      2.0000, Y1=      0.0000, Z1=     -2.0000, NPT1= 20,        &END
&VS4     X2=     -2.0000, Y2=      0.0000, Z2=     -2.0000, NPT2=  0,        &END
&VS5     X3=     -2.0000, Y3=      0.0000, Z3=      2.0000, NPT3= 40,        &END
&VS6     XR0=     0.0000, YR0=     0.0000, ZR0=     0.0000,                  &END
&VS7     XR1=     0.0000, YR1=    10.0000, ZR1=     0.0000,
         XR2=     0.0000, YR2=     0.0000, ZR2=     1.0000,                  &END
&VS8     R1=      0.5000, R2=      5.0000, PHI1=   0.0,     PHI2=330.0,      &END
&VS9     NRAD=  10,       NPHI=  12,       NLEN=   5,                        &END

 &SLIN1   NSTLIN=0,                                                          &END
 &SLIN2   SX0=    -3.0000, SY0=     0.0000, SZ0=     0.0500,
          SU=      0.0000, SD=      6.5000, DS=      0.0250,                 &END
```

APPENDIX G
PMARC INPUT DATA FOR PIONEER (SMALL TAIL)

```
PIONEER SMALL TAIL

&BINP2    LSTINP=2,      LSTOUT=1,     LSTFRQ=0,     LENRUN=2,                     &END
&BINP3    LSTGEO=2,      LSTNAB=0,     LSTWAK=3,     LSTCPV=0,     LSTJET=0,       &END
&BINP4    MAXIT=75,      SOLRES=0.0005,                                            &END
&BINP5    NTSTPS=5,      DTSTEP=0.5,                                               &END
&BINP6    RSYM=0.0,      RGPR=0.0,     RFP=5.0,      RCORE=0.05,                   &END
&BINP7    VINP=1.00,     VSOUND=1116.0,              UNIT=0,       COMPOP=0.0,     &END
&BINP8    ALDEG=-2.0,    YAWDEG=0.0,   THEDOT=0.0,   PSIDOT=0.0,   PHIDOT=0.0,     &END
&BINP9    CBAR=1.0,      SREF=9.1,    SSPAN=4.55,
          RMPX=0.33,     RMPY=0.00,    RMPZ=0.00,                                  &END
&BINP10   NORSET=0,      NBCHGE=0,     NCZONE=0,
          NCZPAN=0,      CZDUB=0.0,    VREF=0.0,                                   &END
&BINP11   NORPCH=0,      NORF=0,       NORL=0,
          NOCP=0,        NOCL=0,       VNORM=0.0,                                  &END
&BINP12   KPAN=0,        KSIDE=0,      NEWNAB=0,     NEWSID=0,                     &END


&ASEM1    ASEMX=0.00,       ASEMY=0.00,       ASEMZ=0.00,
          ASCAL=1.00,       ATHET=0.00,       NODEA=5,                             &END
&ASEM2    APXX=0.00,        APYY=0.00,        APZZ=0.00,
          AHXX=0.00,        AHYY=1.00,        AHZZ=0.00,                           &END


&COMP1    COMPX= 0.0000,    COMPY= 0.0000,    COMPZ= 0.0000,
          CSCAL=  1.000   , CTHET=   0.0,     NODEC= 5,                            &END
&COMP2    CPXX= 0.0000,     CPYY= 0.0000,     CPZZ= 0.0000,
          CHXX= 0.0000,     CHYY=  1.000   ,  CHZZ= 0.0000,                        &END


&PATCH1   IREV=  0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,             &END
           WING
&SECT1    STX=     0.0000, STY= 0.2545,    STZ= 0.0000,    SCALE=  1.000    ,
          ALF=   3.0,  THETA=   0.0,
          INMODE=  5,  TNODS= 0,    TNPS=  0,    TINTS= 0,                         &END
&SECT2    RTC=     0.1500, RMC= 0.0400,    RPC= 0.4000,
          IPLANE=  2,  TNPC= 15,    TINTC= 0,                                      &END
&SECT1    STX=     0.0000, STY= .8200,    STZ= 0.0000,    SCALE=  1.000    ,
          ALF=   3.0,  THETA=  0.0,
          INMODE=  0,  TNODS= 3,    TNPS= 5,    TINTS= 0,                          &END


&PATCH1   IREV=  0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,             &END
           WING/BOOM JUNCTION

&SECT1    STX=     0.0000, STY= 0.8200,    STZ= 0.0000,    SCALE=  1.000    ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 0,    TNPS=  0,    TINTS= 0,                         &END
    0.9986  0.0      -0.0523
&BPNODE  TNODE = 4,  TNPC = 0,  TINTC = 3,                                         &END
    0.9871  0.0      -0.0541
    0.9549  0.0      -0.0534
    0.9021  0.0      -0.0528
    0.8312  0.0      -0.0523
    0.7454  0.0      -0.0521
    0.6486  0.0      -0.0523
    0.5450  0.0      -0.0530
    0.4390  0.0      -0.0535
    0.3354  0.0      -0.0533
    0.2386  0.0      -0.0528
```

```
   0.1529  0.0      -0.0500
   0.0823  0.0      -0.0428
   0.0308  0.0      -0.0299
   0.0059  0.0      -0.0094
   0.0000  0.0       0.0000
  -0.0005  0.0       0.0117
   0.0222  0.0       0.0363
   0.0706  0.0       0.0620
   0.1412  0.0       0.0821
   0.2293  0.0       0.0942
   0.3297  0.0       0.0963
   0.4369  0.0       0.0881
   0.5456  0.0       0.0722
   0.6511  0.0       0.0515
   0.7488  0.0       0.0280
   0.8344  0.0       0.0041
   0.9046  0.0      -0.0178
   0.9566  0.0      -0.0354
   0.9882  0.0      -0.0464
   0.9986  0.0      -0.0523
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END

&SECT1   STX=    0.0000, STY= 0.8482,    STZ= 0.0000,    SCALE=  1.000    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 0,    TNPS=  0,    TINTS= 0,                    &END
   0.9986  0.0       0.0
&BPNODE  TNODE = 4,  TNPC = 0,  TINTC = 3,                                   &END
   0.9871  0.0      -0.0100
   0.9549  0.0      -0.0200
   0.9021  0.0      -0.0300
   0.8312  0.0      -0.0400
   0.7454  0.0      -0.0521
   0.6486  0.0      -0.0523
   0.5450  0.0      -0.0530
   0.4390  0.0      -0.0535
   0.3354  0.0      -0.0533
   0.2386  0.0      -0.0528
   0.1529  0.0      -0.0500
   0.0823  0.0      -0.0428
   0.0308  0.0      -0.0299
   0.0059  0.0      -0.0094
   0.0000  0.0       0.0000
  -0.0005  0.0       0.0117
   0.0222  0.0       0.0363
   0.0706  0.0       0.0620
   0.1412  0.0       0.0821
   0.2293  0.0       0.0942
   0.3297  0.0       0.0963
   0.4369  0.0       0.0881
   0.5456  0.0       0.0722
   0.6511  0.0       0.0515
   0.7488  0.0       0.0280
   0.8344  0.0       0.0041
   0.9046  0.0       0.0
   0.9566  0.0       0.0
   0.9882  0.0       0.0
   0.9986  0.0       0.0
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END

&SECT1   STX=    0.0000, STY= 0.8576,    STZ= 0.0000,    SCALE=  1.000    ,
```

```
        ALF=   0.0,  THETA=   0.0,
        INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                   &END
  0.9986  0.0     -0.0350
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                 &END
  0.9871  0.0     -0.0400
  0.9549  0.0     -0.0450
  0.9021  0.0     -0.0500
  0.8312  0.0     -0.0523
  0.7454  0.0     -0.0521
  0.6486  0.0     -0.0523
  0.5450  0.0     -0.0530
  0.4390  0.0     -0.0535
  0.3354  0.0     -0.0533
  0.2386  0.0     -0.0528
  0.1529  0.0     -0.0500
  0.0823  0.0     -0.0428
  0.0308  0.0     -0.0299
  0.0059  0.0     -0.0094
  0.0000  0.0      0.0000
 -0.0005  0.0      0.0117
  0.0222  0.0      0.0363
  0.0706  0.0      0.0620
  0.1412  0.0      0.0821
  0.2293  0.0      0.0942
  0.3297  0.0      0.0963
  0.4369  0.0      0.0881
  0.5456  0.0      0.0722
  0.6511  0.0      0.0515
  0.7488  0.0      0.0350
  0.8344  0.0      0.0350
  0.9046  0.0      0.0350
  0.9566  0.0      0.0350
  0.9882  0.0      0.0350
  0.9986  0.0      0.0350
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                 &END

&SECT1   STX=    0.0000, STY= 0.8832,    STZ= 0.0000,    SCALE=  1.000   ,
        ALF=   0.0,  THETA=   0.0,
        INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                   &END
  0.9986  0.0     -0.0606
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                 &END
  0.9871  0.0     -0.0606
  0.9549  0.0     -0.0606
  0.9021  0.0     -0.0606
  0.8312  0.0     -0.0606
  0.7454  0.0     -0.0606
  0.6486  0.0     -0.0606
  0.5450  0.0     -0.0606
  0.4390  0.0     -0.0535
  0.3354  0.0     -0.0533
  0.2386  0.0     -0.0528
  0.1529  0.0     -0.0500
  0.0823  0.0     -0.0428
  0.0308  0.0     -0.0299
  0.0059  0.0     -0.0094
  0.0000  0.0      0.0000
 -0.0005  0.0      0.0117
  0.0222  0.0      0.0363
  0.0706  0.0      0.0620
  0.1412  0.0      0.0821
```

```
   0.2293  0.0      0.0942
   0.3297  0.0      0.0963
   0.4369  0.0      0.0881
   0.5456  0.0      0.0722
   0.6511  0.0      0.0606
   0.7488  0.0      0.0606
   0.8344  0.0      0.0606
   0.9046  0.0      0.0606
   0.9566  0.0      0.0606
   0.9882  0.0      0.0606
   0.9986  0.0      0.0606
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                    &END

&SECT1   STX=    0.0000, STY= 0.9182,   STZ= 0.0000,   SCALE=  1.000    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                     &END
   0.9986  0.0     -0.0700
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                    &END
   0.9871  0.0     -0.0700
   0.9549  0.0     -0.0700
   0.9021  0.0     -0.0700
   0.8312  0.0     -0.0700
   0.7454  0.0     -0.0700
   0.6486  0.0     -0.0700
   0.5450  0.0     -0.0700
   0.4390  0.0     -0.0535
   0.3354  0.0     -0.0533
   0.2386  0.0     -0.0528
   0.1529  0.0     -0.0500
   0.0823  0.0     -0.0428
   0.0308  0.0     -0.0299
   0.0059  0.0     -0.0094
   0.0000  0.0      0.0000
  -0.0005  0.0      0.0117
   0.0222  0.0      0.0363
   0.0706  0.0      0.0620
   0.1412  0.0      0.0821
   0.2293  0.0      0.0942
   0.3297  0.0      0.0963
   0.4369  0.0      0.0881
   0.5456  0.0      0.0722
   0.6511  0.0      0.0700
   0.7488  0.0      0.0700
   0.8344  0.0      0.0700
   0.9046  0.0      0.0700
   0.9566  0.0      0.0700
   0.9882  0.0      0.0700
   0.9986  0.0      0.0700
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                    &END

&SECT1   STX=    0.0000, STY= 0.9532,   STZ= 0.0000,   SCALE=  1.000    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                     &END
   0.9986  0.0     -0.0606
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                    &END
   0.9871  0.0     -0.0606
   0.9549  0.0     -0.0606
   0.9021  0.0     -0.0606
   0.8312  0.0     -0.0606
   0.7454  0.0     -0.0606
```

```
      0.6486  0.0      -0.0606
      0.5450  0.0      -0.0606
      0.4390  0.0      -0.0535
      0.3354  0.0      -0.0533
      0.2386  0.0      -0.0528
      0.1529  0.0      -0.0500
      0.0823  0.0      -0.0428
      0.0308  0.0      -0.0299
      0.0059  0.0      -0.0094
      0.0000  0.0       0.0000
     -0.0005  0.0       0.0117
      0.0222  0.0       0.0363
      0.0706  0.0       0.0620
      0.1412  0.0       0.0821
      0.2293  0.0       0.0942
      0.3297  0.0       0.0963
      0.4369  0.0       0.0881
      0.5456  0.0       0.0722
      0.6511  0.0       0.0606
      0.7488  0.0       0.0606
      0.8344  0.0       0.0606
      0.9046  0.0       0.0606
      0.9566  0.0       0.0606
      0.9882  0.0       0.0606
      0.9986  0.0       0.0606
 &BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                  &END

 &SECT1   STX=    0.0000, STY= 0.9788,    STZ= 0.0000,    SCALE=  1.000   ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                   &END
      0.9986  0.0      -0.0350
 &BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                  &END
      0.9871  0.0      -0.0400
      0.9549  0.0      -0.0450
      0.9021  0.0      -0.0500
      0.8312  0.0      -0.0523
      0.7454  0.0      -0.0521
      0.6486  0.0      -0.0523
      0.5450  0.0      -0.0530
      0.4390  0.0      -0.0535
      0.3354  0.0      -0.0533
      0.2386  0.0      -0.0528
      0.1529  0.0      -0.0500
      0.0823  0.0      -0.0428
      0.0308  0.0      -0.0299
      0.0059  0.0      -0.0094
      0.0000  0.0       0.0000
     -0.0005  0.0       0.0117
      0.0222  0.0       0.0363
      0.0706  0.0       0.0620
      0.1412  0.0       0.0821
      0.2293  0.0       0.0942
      0.3297  0.0       0.0963
      0.4369  0.0       0.0881
      0.5456  0.0       0.0722
      0.6511  0.0       0.0515
      0.7488  0.0       0.0350
      0.8344  0.0       0.0350
      0.9046  0.0       0.0350
      0.9566  0.0       0.0350
```

```
   0.9882  0.0       0.0350
   0.9986  0.0       0.0350
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                     &END

&SECT1   STX=     0.0000, STY= 0.9882,    STZ= 0.0000,    SCALE=  1.000    ,
         ALF=   0.0,  THETA=   0.0,
         INNODE=  4,  TNODS= 0,    TNPS=  0,    TINTS= 0,                      &END
   0.9986  0.0       0.0
&BPNODE  TNODE = 4,  TNPC = 0,  TINTC = 3,                                     &END
   0.9871  0.0      -0.0100
   0.9549  0.0      -0.0200
   0.9021  0.0      -0.0300
   0.8312  0.0      -0.0400
   0.7454  0.0      -0.0521
   0.6486  0.0      -0.0523
   0.5450  0.0      -0.0530
   0.4390  0.0      -0.0535
   0.3354  0.0      -0.0533
   0.2386  0.0      -0.0528
   0.1529  0.0      -0.0500
   0.0823  0.0      -0.0428
   0.0308  0.0      -0.0299
   0.0059  0.0      -0.0094
   0.0000  0.0       0.0000
  -0.0005  0.0       0.0117
   0.0222  0.0       0.0363
   0.0706  0.0       0.0620
   0.1412  0.0       0.0821
   0.2293  0.0       0.0942
   0.3297  0.0       0.0963
   0.4369  0.0       0.0881
   0.5456  0.0       0.0722
   0.6511  0.0       0.0515
   0.7488  0.0       0.0280
   0.8344  0.0       0.0041
   0.9046  0.0       0.0
   0.9566  0.0       0.0
   0.9882  0.0       0.0
   0.9986  0.0       0.0
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                     &END

&SECT1   STX=     0.0000, STY= 1.0,    STZ= 0.0000,    SCALE=  1.000    ,
         ALF=   0.0,  THETA=   0.0,
         INNODE=  4,  TNODS= 3,    TNPS=  0,    TINTS= 0,                      &END
   0.9986  0.0      -0.0523
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                     &END
   0.9871  0.0      -0.0541
   0.9549  0.0      -0.0534
   0.9021  0.0      -0.0528
   0.8312  0.0      -0.0523
   0.7454  0.0      -0.0521
   0.6486  0.0      -0.0523
   0.5450  0.0      -0.0530
   0.4390  0.0      -0.0535
   0.3354  0.0      -0.0533
   0.2386  0.0      -0.0528
   0.1529  0.0      -0.0500
   0.0823  0.0      -0.0428
   0.0308  0.0      -0.0299
   0.0059  0.0      -0.0094
```

```
   0.0000  0.0      0.0000
  -0.0005  0.0      0.0117
   0.0222  0.0      0.0363
   0.0706  0.0      0.0620
   0.1412  0.0      0.0821
   0.2293  0.0      0.0942
   0.3297  0.0      0.0963
   0.4369  0.0      0.0881
   0.5456  0.0      0.0722
   0.6511  0.0      0.0515
   0.7488  0.0      0.0280
   0.8344  0.0      0.0041
   0.9046  0.0     -0.0178
   0.9566  0.0     -0.0354
   0.9882  0.0     -0.0464
   0.9986  0.0     -0.0523
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                    &END

&PATCH1  IREV=  0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,     &END
         OUTER WING

&SECT1   STX=    0.0000, STY= 1.0,     STZ= 0.0000,    SCALE=  1.000    ,
         ALF=   3.0,  THETA=   0.0,
         INMODE=  5,  TNODS= 0,    TNPS=  0,    TINTS= 0,                   &END
&SECT2   RTC=    0.1500, RMC= 0.0400,     RPC= 0.4000,
         IPLANE=  2,  TNPC= 15,    TINTC= 0,                                &END
&SECT1   STX=    0.0000, STY= 4.550,    STZ= 0.0000,    SCALE=  1.000    ,
         ALF=   3.0,  THETA=   0.0,
         INMODE=  0,  TNODS= 3,    TNPS= 8,    TINTS= 0,                    &END

&PATCH1  IREV=  0,    IDPAT= 1,    MAKE=   3,   KCOMP= 1,    KASS= 1,     &END
          WING TIP
&PATCH2  ITYP=  1,    TNODS= 3,    TNPS=   3,   TINTS= 3,    NPTTIP=0,    &END


&PATCH1  IREV=  0,    IDPAT= 2,    MAKE=   0,   KCOMP= 1,    KASS= 1,     &END
          BOOM

&SECT1   STX=    0.9986, STY= .9182,    STZ= 0.0000,    SCALE=  1.000    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  7,  TNODS= 0,    TNPS=  0,    TINTS= 0,                   &END
         .070   0.0   0.0
&BPNODE          TNODE=  0,  TNPC=  0,  TINTC=0,                            &END
         .070  30.0   0.0
         .070  60.0   0.0
         .070  90.0   0.0
         .070 120.0   0.0
         .070 150.0   0.0
         .070 180.0   0.0
         .070 210.0   0.0
         .070 240.0   0.0
         .070 270.0   0.0
         .070 300.0   0.0
         .070 330.0   0.0
         .070 0.0   0.0
&BPNODE          TNODE=  3,  TNPC=  0,  TINTC=3,                            &END

&SECT1   STX=    4.382, STY= .9182,    STZ= 0.0000,    SCALE=  1.000    ,
        ALF=   0.0,  THETA=   0.0,
        INMODE=  0,  TNODS= 3,    TNPS= 5,    TINTS= 3,                     &END
```

```
&PATCH1  IREV= -1,    IDPAT= 2,    MAKE=   0,   KCOMP= 1,    KASS= 1,       &END
          FUS BOTTOM

&SECT1   STX=   -.0005, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 4,  TNODS= 0,    TNPS=  0,    TINTS= 0,                   &END
         0.0  .2545   .0117
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                       &END
         0.0  .2727  -.1395
         0.0  .2909  -.2908
         0.0  .3182  -.4363
         0.0  .3454  -.5817
         0.0  .3636  -.6817
         0.0  .3545  -.7090
         0.0  .3273  -.7726
         0.0  .2727  -.7726
         0.0  .1364  -.7726
         0.0  0.0    -.7726
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                       &END

&SECT1   STX=    0.0059, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                   &END
         0.0  .2545    -.0094
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                       &END
         0.0  .2727  -.1395
         0.0  .2909  -.2908
         0.0  .3182  -.4363
         0.0  .3454  -.5817
         0.0  .3636  -.6817
         0.0  .3545  -.7090
         0.0  .3273  -.7726
         0.0  .2727  -.7726
         0.0  .1364  -.7726
         0.0  0.0    -.7726
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                       &END

&SECT1   STX=    0.0308, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                   &END
         0.0  .2545    -.0299
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                       &END
         0.0  .2727  -.1395
         0.0  .2909  -.2908
         0.0  .3182  -.4363
         0.0  .3454  -.5817
         0.0  .3636  -.6817
         0.0  .3545  -.7090
         0.0  .3273  -.7726
         0.0  .2727  -.7726
         0.0  .1364  -.7726
         0.0  0.0    -.7726
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                       &END

&SECT1   STX=    0.0823, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                   &END
         0.0  .2545    -.0428
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                       &END
```

```
          0.0  .2727  -.1395
          0.0  .2909  -.2908
          0.0  .3182  -.4363
          0.0  .3454  -.5817
          0.0  .3636  -.6817
          0.0  .3545  -.7090
          0.0  .3273  -.7726
          0.0  .2727  -.7726
          0.0  .1364  -.7726
          0.0  0.0    -.7726
&BPNODE   TNODE=3,  TNPC=0,  TINTC=3,                                                   &END

&SECT1    STX=    0.1529, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
          ALF=   0.0,  THETA=   0.0,
          INNODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                              &END
          0.0  .2545    -.0500
&BPNODE   TNODE=0,  TNPC=0,  TINTC=3,                                                   &END
          0.0  .2727  -.1395
          0.0  .2909  -.2908
          0.0  .3182  -.4363
          0.0  .3454  -.5817
          0.0  .3636  -.6817
          0.0  .3545  -.7090
          0.0  .3273  -.7726
          0.0  .2727  -.7726
          0.0  .1364  -.7726
          0.0  0.0    -.7726
&BPNODE   TNODE=3,  TNPC=0,  TINTC=3,                                                   &END

&SECT1    STX=    0.2386, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
          ALF=   0.0,  THETA=   0.0,
          INNODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                              &END
          0.0  .2545    -.0528
&BPNODE   TNODE=0,  TNPC=0,  TINTC=3,                                                   &END
          0.0  .2727  -.1395
          0.0  .2909  -.2908
          0.0  .3182  -.4363
          0.0  .3454  -.5817
          0.0  .3636  -.6817
          0.0  .3545  -.7090
          0.0  .3273  -.7726
          0.0  .2727  -.7726
          0.0  .1364  -.7726
          0.0  0.0    -.7726
&BPNODE   TNODE=3,  TNPC=0,  TINTC=3,                                                   &END

&SECT1    STX=    0.3354, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
          ALF=   0.0,  THETA=   0.0,
          INNODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                              &END
          0.0  .2545    -.0533
&BPNODE   TNODE=0,  TNPC=0,  TINTC=3,                                                   &END
          0.0  .2727  -.1395
          0.0  .2909  -.2908
          0.0  .3182  -.4363
          0.0  .3454  -.5817
          0.0  .3636  -.6817
          0.0  .3545  -.7090
          0.0  .3273  -.7726
          0.0  .2727  -.7726
          0.0  .1364  -.7726
```

```
        0.0  0.0    -.7726
&BPNODE TNODE=3,  TNPC=0,  TINTC=3,                                        &END

&SECT1  STX=    0.4390, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
        ALF=   0.0,  THETA=   0.0,
        INNODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                   &END
        0.0  .2545    -.0535
&BPNODE TNODE=0,  TNPC=0,  TINTC=3,                                        &END
        0.0  .2727  -.1395
        0.0  .2909  -.2908
        0.0  .3182  -.4363
        0.0  .3454  -.5817
        0.0  .3636  -.6817
        0.0  .3545  -.7090
        0.0  .3273  -.7726
        0.0  .2727  -.7726
        0.0  .1364  -.7726
        0.0  0.0    -.7726
&BPNODE TNODE=3,  TNPC=0,  TINTC=3,                                        &END

&SECT1  STX=    0.5450, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
        ALF=   0.0,  THETA=   0.0,
        INNODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                   &END
        0.0  .2545    -.0530
&BPNODE TNODE=0,  TNPC=0,  TINTC=3,                                        &END
        0.0  .2727  -.1395
        0.0  .2909  -.2908
        0.0  .3182  -.4363
        0.0  .3454  -.5817
        0.0  .3636  -.6817
        0.0  .3545  -.7090
        0.0  .3273  -.7726
        0.0  .2727  -.7726
        0.0  .1364  -.7726
        0.0  0.0    -.7726
&BPNODE TNODE=3,  TNPC=0,  TINTC=3,                                        &END

&SECT1  STX=    0.6486, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
        ALF=   0.0,  THETA=   0.0,
        INNODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                   &END
        0.0  .2545    -.0523
&BPNODE TNODE=0,  TNPC=0,  TINTC=3,                                        &END
        0.0  .2727  -.1395
        0.0  .2909  -.2908
        0.0  .3182  -.4363
        0.0  .3454  -.5817
        0.0  .3636  -.6817
        0.0  .3545  -.7090
        0.0  .3273  -.7726
        0.0  .2727  -.7726
        0.0  .1364  -.7726
        0.0  0.0    -.7726
&BPNODE TNODE=3,  TNPC=0,  TINTC=3,                                        &END

&SECT1  STX=    0.7454, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
        ALF=   0.0,  THETA=   0.0,
        INNODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                   &END
        0.0  .2545    -.0521
&BPNODE TNODE=0,  TNPC=0,  TINTC=3,                                        &END
        0.0  .2727  -.1395
```

```
         0.0  .2909  -.2908
         0.0  .3182  -.4363
         0.0  .3454  -.5817
         0.0  .3636  -.6817
         0.0  .3545  -.7090
         0.0  .3273  -.7726
         0.0  .2727  -.7726
         0.0  .1364  -.7726
         0.0  0.0    -.7726
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                      &END

&SECT1   STX=    0.8312, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                 &END
         0.0  .2545    -.0523
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                      &END
         0.0  .2727  -.1395
         0.0  .2909  -.2908
         0.0  .3182  -.4363
         0.0  .3454  -.5817
         0.0  .3636  -.6817
         0.0  .3545  -.7090
         0.0  .3273  -.7726
         0.0  .2727  -.7726
         0.0  .1364  -.7726
         0.0  0.0    -.7726
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                      &END

&SECT1   STX=    0.9021, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                 &END
         0.0  .2545    -.0528
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                      &END
         0.0  .2727  -.1395
         0.0  .2909  -.2908
         0.0  .3182  -.4363
         0.0  .3454  -.5817
         0.0  .3636  -.6817
         0.0  .3545  -.7090
         0.0  .3273  -.7726
         0.0  .2727  -.7726
         0.0  .1364  -.7726
         0.0  0.0    -.7726
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                      &END

&SECT1   STX=    0.9549, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 3,                 &END
         0.0  .2545    -.0534
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                      &END
         0.0  .2727  -.1395
         0.0  .2909  -.2908
         0.0  .3182  -.4363
         0.0  .3454  -.5817
         0.0  .3636  -.6817
         0.0  .3545  -.7C90
         0.0  .3273  -.7726
         0.0  .2727  -.7726
         0.0  .1364  -.7726
         0.0  0.0    -.7726
```

```
           0.0  .2545   .0550
           0.0  .2545   .0750
&BPNODE    TNODE=2,  TNPC=0,  TINTC=3,                                                     &END
           0.0  .2200   .0970
&BPNODE    TNODE=2,  TNPC=0,  TINTC=3,                                                     &END
           0.0  .1800   .0970
           0.0  .0900   .0970
           0.0  0.0     .0970
&BPNODE    TNODE=3,  TNPC=0,  TINTC=3,                                                     &END

&SECT1     STX=   0.0706, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000    ,
           ALF=   0.0,  THETA=   0.0,
           INNODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                                &END
           0.0  .2545   .0620
&BPNODE    TNODE=0,  TNPC=0,  TINTC=3,                                                     &END
           0.0  .2545   .0720
           0.0  .2545   .0850
&BPNODE    TNODE=2,  TNPC=0,  TINTC=3,                                                     &END
           0.0  .2200   .0980
&BPNODE    TNODE=2,  TNPC=0,  TINTC=3,                                                     &END
           0.0  .1800   .0980
           0.0  .0900   .0980
           0.0  0.0     .0980
&BPNODE    TNODE=3,  TNPC=0,  TINTC=3,                                                     &END

&SECT1     STX=   0.1412, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000    ,
           ALF=   0.0,  THETA=   0.0,
           INNODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                                &END
           0.0  .2545   .0821
&BPNODE    TNODE=0,  TNPC=0,  TINTC=3,                                                     &END
           0.0  .2545   .0880
           0.0  .2545   .0930
&BPNODE    TNODE=2,  TNPC=0,  TINTC=3,                                                     &END
           0.0  .2200   .0985
&BPNODE    TNODE=2,  TNPC=0,  TINTC=3,                                                     &END
           0.0  .1800   .0985
           0.0  .0900   .0985
           0.0  0.0     .0985
&BPNODE    TNODE=3,  TNPC=0,  TINTC=3,                                                     &END

&SECT1     STX=   0.2293, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000    ,
           ALF=   0.0,  THETA=   0.0,
           INNODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                                &END
           0.0  .2545   .0942
&BPNODE    TNODE=0,  TNPC=0,  TINTC=3,                                                     &END
           0.0  .2545   .0960
           0.0  .2545   .0975
&BPNODE    TNODE=2,  TNPC=0,  TINTC=3,                                                     &END
           0.0  .2200   .0990
&BPNODE    TNODE=2,  TNPC=0,  TINTC=3,                                                     &END
           0.0  .1800   .0990
           0.0  .0900   .0990
           0.0  0.0     .0990
&BPNODE    TNODE=3,  TNPC=0,  TINTC=3,                                                     &END

&SECT1     STX=   0.3297, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000    ,
           ALF=   0.0,  THETA=   0.0,
           INNODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                                &END
           0.0  .2545   .0963
&BPNODE    TNODE=0,  TNPC=0,  TINTC=3,                                                     &END
```

```
         0.0  .2545   .0975
         0.0  .2545   .0985
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                        &END
         0.0  .2200   .1
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                        &END
         0.0  .1800   .1
         0.0  .0900   .1
         0.0  0.0     .1
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                        &END

&SECT1   STX=   0.4369, STY= 0.0000,   STZ= 0.0000,   SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                   &END
         0.0  .2545   .0881
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                        &END
         0.0  .2545   .0900
         0.0  .2545   .0950
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                        &END
         0.0  .2200   .0990
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                        &END
         0.0  .1800   .0990
         0.0  .0900   .0990
         0.0  0.0     .0990
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                        &END

&SECT1   STX=   0.5456, STY= 0.0000,   STZ= 0.0000,   SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                   &END
         0.0  .2545   .0722
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                        &END
         0.0  .2545   .0800
         0.0  .2545   .0900
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                        &END
         0.0  .2200   .0980
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                        &END
         0.0  .1800   .0980
         0.0  .0900   .0980
         0.0  0.0     .0980
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                        &END

&SECT1   STX=   0.6511, STY= 0.0000,   STZ= 0.0000,   SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                   &END
         0.0  .2545   .0515
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                        &END
         0.0  .2545   .0700
         0.0  .2545   .0820
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                        &END
         0.0  .2200   .0970
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                        &END
         0.0  .1800   .0970
         0.0  .0900   .0970
         0.0  0.0     .0970
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                        &END

&SECT1   STX=    .7488, STY= 0.0000,   STZ= 0.0000,   SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,                   &END
         0.0  .2545   .0280
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                        &END
```

```
          0.0  .2545   .0450
          0.0  .2545   .0650
&BPNODE   TNODE=2,  TNPC=0,  TINTC=3,                                  &END
          0.0  .2200   .0970
&BPNODE   TNODE=2,  TNPC=0,  TINTC=3,                                  &END
          0.0  .1800   .0970
          0.0  .0900   .0970
          0.0  0.0     .0970
&BPNODE   TNODE=3,  TNPC=0,  TINTC=3,                                  &END

&SECT1    STX=   .8344, STY= 0.0000,   STZ= 0.0000,   SCALE=  1.000   ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,             &END
          0.0  .2545   .0041
&BPNODE   TNODE=0,  TNPC=0,  TINTC=3,                                  &END
          0.0  .2545   .0350
          0.0  .2545   .0650
&BPNODE   TNODE=2,  TNPC=0,  TINTC=3,                                  &END
          0.0  .2200   .0970
&BPNODE   TNODE=2,  TNPC=0,  TINTC=3,                                  &END
          0.0  .1800   .0970
          0.0  .0900   .0970
          0.0  0.0     .0970
&BPNODE   TNODE=3,  TNPC=0,  TINTC=3,                                  &END

&SECT1    STX=   0.9046, STY= 0.0000,   STZ= 0.0000,   SCALE=  1.000   ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,             &END
          0.0  .2545   -.0178
&BPNODE   TNODE=0,  TNPC=0,  TINTC=3,                                  &END
          0.0  .2545   .0300
          0.0  .2545   .0650
&BPNODE   TNODE=2,  TNPC=0,  TINTC=3,                                  &END
          0.0  .2200   .0970
&BPNODE   TNODE=2,  TNPC=0,  TINTC=3,                                  &END
          0.0  .1800   .0970
          0.0  .0900   .0970
          0.0  0.0     .0970
&BPNODE   TNODE=3,  TNPC=0,  TINTC=3,                                  &END

&SECT1    STX=   .9566, STY= 0.0000,   STZ= 0.0000,   SCALE=  1.000   ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,             &END
          0.0  .2545   -.0354
&BPNODE   TNODE=0,  TNPC=0,  TINTC=3,                                  &END
          0.0  .2545   .0150
          0.0  .2545   .0500
&BPNODE   TNODE=2,  TNPC=0,  TINTC=3,                                  &END
          0.0  .2200   .0970
&BPNODE   TNODE=2,  TNPC=0,  TINTC=3,                                  &END
          0.0  .1800   .0970
          0.0  .0900   .0970
          0.0  0.0     .0970
&BPNODE   TNODE=3,  TNPC=0,  TINTC=3,                                  &END

&SECT1    STX=   .9882, STY= 0.0000,   STZ= 0.0000,   SCALE=  1.000   ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 2,    TNPS=  0,    TINTS= 0,             &END
          0.0  .2545   -.0464
&BPNODE   TNODE=0,  TNPC=0,  TINTC=3,                                  &END
```

```
        0.0  .2545   .0050
        0.0  .2545   .0550
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                      &END
        0.0  .2200   .0970
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                      &END
        0.0  .1800   .0970
        0.0  .0900   .0970
        0.0  0.0     .0970
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                      &END

&SECT1   STX=   0.9986, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 3,    TNPS=  0,    TINTS= 0,                 &END
        0.0  .2545   -.0523
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                      &END
        0.0  .2545   0.0
        0.0  .2545   .0500
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                      &END
        0.0  .2200   .0970
&BPNODE  TNODE=2,  TNPC=0,  TINTC=3,                                      &END
        0.0  .1800   .0970
        0.0  .0900   .0970
        0.0  0.0     .0970
&BPNODE  TNODE=3,  TNPC=0,  TINTC=3,                                      &END


&PATCH1  IREV= 0,    IDPAT= 2,    MAKE=   0,   KCOMP= 1,    KASS= 1,      &END
          FUS FORWARD1

&SECT1   STX=   -2.720, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 3,                 &END
         0.0   0.0     -.5816
&BPNODE  TNODE=3,  TNPC=16,  TINTC=3,                                     &END

&SECT1   STX=   -2.686, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  1,    TINTS= 3,                 &END
         0.0   0.0     -.6362
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                      &END
         0.0   .0133  -.6362
         0.0   .0266  -.6362
         0.0   .0400  -.6362
         0.0   .0533  -.6253
         0.0   .0666  -.6144
         0.0   .0666  -.6035
         0.0   .0666  -.5926
         0.0   .0666  -.5816
         0.0   .0666  -.5707
         0.0   .0666  -.5598
         0.0   .0666  -.5489
         0.0   .0666  -.5380
         0.0   .0500  -.5271
         0.0   .0333  -.5271
         0.0   .0166  -.5271
         0.0   0.0    -.5271
&BPNODE  TNODE=3,  TNPC=0, TINTC=3,                                       &END

&SECT1   STX=   -2.386, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
```

```
         INMODE=  4,  TNODS= 2,    TNPS=  4,    TINTS= 3,                   &END
         0.0  0.0   -.7726
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                        &END
         0.0   .0531  -.7726
         0.0   .1062  -.7726
         0.0   .1600  -.7726
         0.0   .2120  -.7090
         0.0   .2653  -.6817
         0.0   .2500  -.6476
         0.0   .2500  -.6135
         0.0   .2500  -.5794
         0.0   .2500  -.5453
         0.0   .2500  -.5112
         0.0   .2500  -.4772
         0.0   .2375  -.4431
         0.0   .2200  -.4090
         0.0   .1800  -.4090
         0.0   .0900  -.4090
         0.0   0.0    -.4090
&BPNODE  TNODE=3,  TNPC=0, TINTC=3,                                         &END

&SECT1   STX=    -1.9770, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000    ,
         ALF=    0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  5,    TINTS= 3,                   &END
         0.0  0.0   -.7726
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                        &END
         0.0   .1364  -.7726
         0.0   .2727  -.7726
         0.0   .3273  -.7726
         0.0   .3545  -.7090
         0.0   .3636  -.6817
         0.0   .3273  -.5950
         0.0   .3182  -.4690
         0.0   .2900  -.3690
         0.0   .2810  -.3270
         0.0   .2727  -.2850
         0.0   .2545  -.2700
         0.0   .2400  -.2600
         0.0   .2200  -.2453
         0.0   .1800  -.2453
         0.0   .0900  -.2453
         0.0   0.0    -.2453
&BPNODE  TNODE=3,  TNPC=0, TINTC=3,                                         &END

&SECT1   STX=    -1.1770, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000    ,
         ALF=    0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  6,    TINTS= 3,                   &END
         0.0  0.0   -.7726
&BPNODE  TNODE=0,  TNPC=0,  TINTC=3,                                        &END
         0.0  .1364  -.7726
         0.0  .2727  -.7726
         0.0  .3273  -.7726
         0.0  .3545  -.7090
         0.0  .3636  -.6817
         0.0  .3454  -.5817
         0.0  .3182  -.4363
         0.0  .2909  -.2908
         0.0  .2727  -.1395
         0.0  .2545   .0117
         0.0  .2545   .0350
```

```
        0.0  .2545   .0650
        0.0  .2200   .0970
        0.0  .1800   .0970
        -0.0  .0900   .0970
        0.0  0.0     .0970
&BPNODE TNODE=3,  TNPC=0, TINTC=3,                                          &END

&SECT1  STX=   -.0005, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
        ALF=   0.0,  THETA=   0.0,
        INMODE=  0,  TNODS= 3,    TNPS=  7,    TINTS= 3,                    &END


&PATCH1 IREV= 0,    IDPAT= 2,    MAKE=  0,   KCOMP= 1,    KASS= 1,          &END
         REAR1

&SECT1  STX=    0.9986, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
        ALF=   0.0,  THETA=   0.0,
        INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 3,                    &END
        0.0  0.0    -.7726
&BPNODE TNODE=0,  TNPC=0,  TINTC=3,                                         &END
        0.0  .1364  -.7726
        0.0  .2727  -.7726
        0.0  .3273  -.7726
        0.0  .3545  -.7090
        0.0  .3636  -.6817
        0.0  .3454  -.5817
        0.0  .3182  -.4363
        0.0  .2909  -.2908
        0.0  .2727  -.1395
        0.0  .2545  -.0523
        0.0  .2545   0.0
        0.0  .2545   .0500
        0.0  .2200   .0970
        0.0  .1800   .0970
        0.0  .0900   .0970
        0.0  0.0     .0970
&BPNODE TNODE=3,  TNPC=0,  TINTC=3,                                         &END


&SECT1  STX=   1.3258, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
        ALF=   0.0,  THETA=   0.0,
        INMODE=  0,  TNODS= 2,    TNPS=  3,    TINTS= 3,                    &END


&SECT1  STX=  1.6348, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
        ALF=   0.0,  THETA=   0.0,
        INMODE=  4,  TNODS= 2,    TNPS=  3,    TINTS= 3,                    &END
        0.0  0.0    -.6826
&BPNODE TNODE=0,  TNPC=0,  TINTC=3,                                         &END
        0.0  .1000   -.6826
        0.0  .2000   -.6826
        0.0  .3191   -.6826
        0.0  .3200   -.6046
        0.0  .3250   -.5267
        0.0  .3086   -.4487
        0.0  .2921   -.3707
        0.0  .2757   -.2928
        0.0  .2593   -.1395
        0.0  .2429   -.0523
        0.0  .2264    0.0
```

```
          0.0  .2100    .0500
          0.0  .1800    .0970
          0.0  .1500    .0970
          0.0  .1000    .0970
          0.0  0.0      .0970
&BPNODE   TNODE=3,  TNPC=0,  TINTC=3,                                   &END

&SECT1    STX=  1.9075, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 2,    TNPS=  3,    TINTS= 3,              &END
          0.0  0.0    -.5000
&BPNODE   TNODE=0,  TNPC=0,  TINTC=3,                                   &END
          0.0  .1200   -.5000
          0.0  .1800   -.5000
          0.0  .2000   -.5000
          0.0  .2050   -.4403
          0.0  .2100   -.3806
          0.0  .2100   -.3209
          0.0  .2100   -.2612
          0.0  .2100   -.2015
          0.0  .2100   -.1418
          0.0  .2100   -.0523
          0.0  .2100   -.0224
          0.0  .2050    .0200
          0.0  .1800    .0670
          0.0  .1500    .0670
          0.0  .1000    .0670
          0.0  0.0      .0670
&BPNODE   TNODE=3,  TNPC=0,  TINTC=3,                                   &END

&SECT1    STX=  2.080, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 2,    TNPS=  3,    TINTS= 3,              &END
          0.0  0.0    -.2636
&BPNODE   TNODE=0,  TNPC=0,  TINTC=3,                                   &END
          0.0  .0300   -.2636
          0.0  .0600   -.2636
          0.0  .0800   -.2636
          0.0  .0825   -.2439
          0.0  .0850   -.2242
          0.0  .0850   -.2045
          0.0  .0850   -.1848
          0.0  .0850   -.1651
          0.0  .0850   -.1454
          0.0  .0850   -.1257
          0.0  .0850   -.1060
          0.0  .0825   -.0863
          0.0  .0700   -.0666
          0.0  .0600   -.0666
          0.0  .0300   -.0666
          0.0  0.0     -.0666
&BPNODE   TNODE=3,  TNPC=0,  TINTC=3,                                   &END

&SECT1    STX=  2.120, STY= 0.0000,    STZ= 0.0000,    SCALE=  1.000   ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 5,    TNPS=  2,    TINTS= 3,              &END
          0.0  0.0    -.1651
&BPNODE   TNODE=3,  TNPC=16,  TINTC=3,                                  &END

&PATCH1   IREV=  0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,  &END
```

```
        TAIL JUNCTION PATCH1

&SECT1   STX=     0.0, STY= 0.,     STZ= 0.000,    SCALE= 1.0    ,
         ALF=   0.0,  THETA=    0.0,
         INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 3,                       &END
   4.6545    0.8300    0.0000
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                      &END
   4.6563    0.8300    0.0058
   4.6708    0.8300    0.0163
   4.6984    0.8300    0.0253
   4.7366    0.8300    0.0322
   4.7834    0.8300    0.0367
   4.8365    0.8300    0.0390
   4.8933    0.8300    0.0391
   4.9514    0.8300    0.0375
   5.0082    0.8300    0.0349
   5.0612    0.8300    0.0316
   5.1081    0.8300    0.0281
   5.1469    0.8300    0.0248
   5.1758    0.8300    0.0222
   5.1933    0.8300    0.0205
   5.1996    0.8300    0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                      &END

&SECT1   STX=     0.0, STY= 0.,     STZ= 0.000,    SCALE= 1.0    ,
         ALF=   0.0,  THETA=    0.0,
         INMODE=  4,  TNODS= 3,    TNPS=  1,    TINTS= 3,                       &END
   4.6545    0.9068    0.0645
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                      &END
   4.6565    0.9012    0.0615
   4.6713    0.8914    0.0584
   4.6992    0.8835    0.0554
   4.7377    0.8807    0.0524
   4.7846    0.8778    0.0493
   4.8377    0.8774    0.0463
   4.8945    0.8820    0.0433
   4.9526    0.8855    0.0402
   5.0092    0.8900    0.0372
   5.0621    0.8951    0.0342
   5.1088    0.9025    0.0311
   5.1475    0.9071    0.0281
   5.1762    0.9107    0.0251
   5.1937    0.9129    0.0220
   5.1999    0.9146    0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                      &END


&PATCH1  IREV= -1,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,           &END
          TAIL JUNCTION PATCH2

&SECT1   STX=     0.0, STY= 0.,     STZ= 0.000,    SCALE= 1.0    ,
         ALF=   0.0,  THETA=    0.0,
         INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 3,                       &END
   4.6545    0.8300    0.0000
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                      &END
   4.6567    0.8300   -0.0057
   4.6719    0.8300   -0.0151
   4.7000    0.8300   -0.0221
   4.7387    0.8300   -0.0264
   4.7857    0.8300   -0.0277
```

```
    4.8388     0.8300    -0.0262
    4.8955     0.8300    -0.0223
    4.9533     0.8300    -0.0167
    5.0098     0.8300    -0.0101
    5.0624     0.8300    -0.0032
    5.1090     0.8300     0.0036
    5.1474     0.8300     0.0096
    5.1760     0.8300     0.0143
    5.1935     0.8300     0.0171
    5.1996     0.8300     0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                  &END

&SECT1   STX=     0.0, STY= 0.,     STZ= 0.000,     SCALE= 1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 3,    TNPS=  1,    TINTS= 3,                   &END
   4.6545     0.9296    -0.0645
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                  &END
    4.6565     0.9239    -0.0589
    4.6713     0.9141    -0.0534
    4.6992     0.9035    -0.0478
    4.7377     0.8954    -0.0422
    4.7846     0.8900    -0.0366
    4.8377     0.8878    -0.0311
    4.8945     0.8884    -0.0255
    4.9526     0.8919    -0.0200
    5.0092     0.8960    -0.0144
    5.0621     0.9011    -0.0088
    5.1088     0.9061    -0.0033
    5.1475     0.9103     0.0023
    5.1762     0.9126     0.0079
    5.1937     0.9149     0.0134
    5.1999     0.9146     0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                  &END


&PATCH1  IREV=  0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,       &END
           TAIL JUNCTION PATCH3

&SECT1   STX=     0.0, STY= 0.,     STZ= 0.000,     SCALE= 1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 3,                   &END
   4.6545     0.9068     0.0645
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                  &END
    4.6565     0.9125     0.0615
    4.6713     0.9223     0.0584
    4.6992     0.9329     0.0554
    4.7377     0.9384     0.0524
    4.7846     0.9413     0.0493
    4.8377     0.9443     0.0463
    4.8945     0.9424     0.0433
    4.9526     0.9389     0.0402
    5.0092     0.9344     0.0372
    5.0621     0.9317     0.0342
    5.1088     0.9267     0.0311
    5.1475     0.9221     0.0281
    5.1762     0.9185     0.0251
    5.1937     0.9163     0.0220
    5.1999     0.9146     0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                  &END
```

```
&SECT1    STX=     0.0, STY= 0.,     STZ= 0.000,     SCALE= 1.0    ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 3,    TNPS=  1,    TINTS= 3,                &END
   4.6545    0.9882    0.0
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                &END
   5.1999    0.9146    0.0190
&BPNODE  TNODE = 3,  TNPC = 15,  TINTC = 0,                               &END


&PATCH1  IREV= -1,    IDPAT= 1,    MAKE=    0,   KCOMP= 1,    KASS= 1,    &END
           TAIL JUNCTION PATCH4

&SECT1    STX=     0.0, STY= 0.,     STZ= 0.000,     SCALE= 1.0    ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 3,                &END
   4.6545    0.9296   -0.0645
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                &END
   4.6565    0.9352   -0.0589
   4.6713    0.9450   -0.0534
   4.6992    0.9502   -0.0478
   4.7377    0.9530   -0.0422
   4.7846    0.9535   -0.0366
   4.8377    0.9519   -0.0311
   4.8945    0.9489   -0.0255
   4.9526    0.9454   -0.0200
   5.0092    0.9404   -0.0144
   5.0621    0.9353   -0.0088
   5.1088    0.9303   -0.0033
   5.1475    0.9253    0.0023
   5.1762    0.9204    0.0079
   5.1937    0.9182    0.0134
   5.1999    0.9146    0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                &END

&SECT1    STX=     0.0, STY= 0.,     STZ= 0.000,     SCALE= 1.0    ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 3,    TNPS=  1,    TINTS= 3,                &END
   4.6545    0.9882    0.0
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                &END
   5.1999    0.9146    0.0190
&BPNODE  TNODE = 3,  TNPC = 15,  TINTC = 0,                               &END


&PATCH1  IREV=  0,    IDPAT= 1,    MAKE=    0,   KCOMP= 1,    KASS= 1,    &END
           TAIL/BOOM JUNCTION1

&SECT1    STX=    4.3820, STY= 0.,     STZ= 0.000,     SCALE= 1.0    ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 3,                &END
   0.0     0.9182    0.0700
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                &END
   0.0     0.8832    0.0606
   0.0     0.8576    0.0350
   0.0     0.8482    0.0
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                &END

&SECT1    STX=    4.6545, STY= 0.,     STZ= 0.000,     SCALE= 1.0    ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 3,    TNPS=  1,    TINTS= 3,                &END
   0.0     0.9068    .0645
```

```
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                     &END
  0.0     0.8300     0.0
&BPNODE  TNODE = 3,  TNPC = 3,  TINTC = 3,                                     &END

&PATCH1  IREV= 0,    IDPAT= 1,    MAKE=   0,  KCOMP= 1,    KASS= 1,            &END
          TAIL/BOOM JUNCTION2

&SECT1   STX=    4.3820, STY= 0.,    STZ= 0.000,    SCALE= 1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 4,  TNODS= 0,    TNPS=  1,    TINTS= 3,                       &END
  0.0     0.8482     0.0000
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                     &END
  0.0     0.8576     -0.0350
  0.0     0.8832     -0.0606
  0.0     0.9182     -0.0700
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                     &END

&SECT1   STX=    4.6545, STY= 0.,    STZ= 0.000,    SCALE= 1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 4,  TNODS= 3,    TNPS=  1,    TINTS= 3,                       &END
  0.0     0.8300     0.0000
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                     &END
  0.0     0.9296     -0.0645
&BPNODE  TNODE = 3,  TNPC = 3,  TINTC = 3,                                     &END

&PATCH1  IREV= 0,    IDPAT= 1,    MAKE=   0,  KCOMP= 1,    KASS= 1,            &END
          TAIL/BOOM JUNCTION3

&SECT1   STX=    4.3820, STY= 0.,    STZ= 0.000,    SCALE= 1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 4,  TNODS= 0,    TNPS=  1,    TINTS= 3,                       &END
  0.0     0.9182     -0.0700
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                     &END
  0.0     0.9532     -0.0606
  0.0     0.9788     -0.0350
  0.0     0.9882     -0.0
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                     &END

&SECT1   STX=    4.6545, STY= 0.,    STZ= 0.000,    SCALE= 1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 4,  TNODS= 3,    TNPS=  1,    TINTS= 3,                       &END
  0.0     0.9296     -0.0645
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                     &END
  0.0     0.9882     0.0
&BPNODE  TNODE = 3,  TNPC = 3,  TINTC = 3,                                     &END

&PATCH1  IREV= 0,    IDPAT= 1,    MAKE=   0,  KCOMP= 1,    KASS= 1,            &END
          TAIL/BOOM JUNCTION4

&SECT1   STX=    4.3820, STY= 0.,    STZ= 0.000,    SCALE= 1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 4,  TNODS= 0,    TNPS=  1,    TINTS= 3,                       &END
  0.0     0.9882     0.0
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                     &END
  0.0     0.9788     0.0350
  0.0     0.9532     0.0606
  0.0     0.9182     0.0700
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                     &END
```

```
&SECT1   STX=    4.6545, STY= 0.,     STZ= 0.000,    SCALE= 1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 3,    TNPS=  1,    TINTS= 3,                &END
   0.0    0.9882     0.0
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                               &END
   0.0    0.9068     .0645
&BPNODE  TNODE = 3,  TNPC = 3,  TINTC = 3,                               &END


&PATCH1  IREV=  0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,    &END
          VERT TAIL UPPER

&SECT1   STX=     0.0, STY= 0.0,     STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 0,                &END
   5.1999    0.8014    0.6625
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                               &END
   5.1937    0.7997    0.6622
   5.1762    0.7975    0.6618
   5.1475    0.7939    0.6612
   5.1088    0.7893    0.6603
   5.0621    0.7843    0.6595
   5.0092    0.7792    0.6586
   4.9526    0.7746    0.6578
   4.8945    0.7711    0.6571
   4.8377    0.7693    0.6568
   4.7846    0.7697    0.6569
   4.7377    0.7725    0.6574
   4.6992    0.7780    0.6584
   4.6713    0.7859    0.6598
   4.6565    0.7957    0.6615
   4.6545    0.8014    0.6625
   4.6565    0.8070    0.6635
   4.6713    0.8168    0.6652
   4.6992    0.8247    0.6666
   4.7377    0.8302    0.6676
   4.7846    0.8331    0.6681
   4.8377    0.8335    0.6681
   4.8945    0.8316    0.6678
   4.9526    0.8281    0.6672
   5.0092    0.8236    0.6664
   5.0621    0.8185    0.6655
   5.1088    0.8135    0.6646
   5.1475    0.8089    0.6638
   5.1762    0.8053    0.6632
   5.1937    0.8031    0.6628
   5.1999    0.8014    0.6625
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                               &END

&SECT1   STX=     0.0, STY= 0.0,     STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 3,    TNPS=  5,    TINTS= 0,                &END
   5.1999    0.9146    0.0190
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                               &END
   5.1937    0.9129    0.0220
   5.1762    0.9107    0.0251
   5.1475    0.9071    0.0281
   5.1088    0.9025    0.0311
   5.0621    0.8951    0.0342
```

```
   5.0092     0.8900     0.0372
   4.9526     0.8855     0.0402
   4.8945     0.8820     0.0433
   4.8377     0.8774     0.0463
   4.7846     0.8778     0.0493
   4.7377     0.8807     0.0524
   4.6992     0.8835     0.0554
   4.6713     0.8914     0.0584
   4.6565     0.9012     0.0615
   4.6545     0.9068     0.0645
   4.6565     0.9125     0.0615
   4.6713     0.9223     0.0584
   4.6992     0.9329     0.0554
   4.7377     0.9384     0.0524
   4.7846     0.9413     0.0493
   4.8377     0.9443     0.0463
   4.8945     0.9424     0.0433
   4.9526     0.9389     0.0402
   5.0092     0.9344     0.0372
   5.0621     0.9317     0.0342
   5.1088     0.9267     0.0311
   5.1475     0.9221     0.0281
   5.1762     0.9185     0.0251
   5.1937     0.9163     0.0220
   5.1999     0.9146     0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                    &END

&PATCH1  IREV=  0,   IDPAT= 1,    MAKE=   -22,  KCOMP= 1,    KASS= 1,         &END
         UPPER VERT TAIL TIP
&PATCH2  ITYP=  1,    TNODS= 3,    TNPS=   3,   TINTS= 3,    NPTTIP=0,        &END


&PATCH1  IREV=  0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,         &END
          VERT TAIL LOWER

&SECT1   STX=    0.0, STY= 0.0,    STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 3,                     &END
   5.1999     0.9146     0.0190
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                    &END
   5.1937     0.9149     0.0134
   5.1762     0.9126     0.0079
   5.1475     0.9103     0.0023
   5.1088     0.9061    -0.0033
   5.0621     0.9011    -0.0088
   5.0092     0.8960    -0.0144
   4.9526     0.8919    -0.0200
   4.8945     0.8884    -0.0255
   4.8377     0.8878    -0.0311
   4.7846     0.8900    -0.0366
   4.7377     0.8954    -0.0422
   4.6992     0.9035    -0.0478
   4.6713     0.9141    -0.0534
   4.6565     0.9239    -0.0589
   4.6545     0.9296    -0.0645
   4.6565     0.9352    -0.0589
   4.6713     0.9450    -0.0534
   4.6992     0.9502    -0.0478
   4.7377     0.9530    -0.0422
   4.7846     0.9535    -0.0366
```

```
   4.8377     0.9519   -0.0311
   4.8945     0.9489   -0.0255
   4.9526     0.9454   -0.0200
   5.0092     0.9404   -0.0144
   5.0621     0.9353   -0.0088
   5.1088     0.9303   -0.0033
   5.1475     0.9253    0.0023
   5.1762     0.9204    0.0079
   5.1937     0.9182    0.0134
   5.1999     0.9146    0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END


&SECT1   STX=     0.0, STY= 0.0,     STZ= 0.000,     SCALE=  1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 3,    TNPS=  5,     TINTS= 0,                   &END
   5.1999     0.9908   -0.4118
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                   &END
   5.1937     0.9891   -0.4121
   5.1762     0.9869   -0.4125
   5.1475     0.9833   -0.4132
   5.1088     0.9787   -0.4140
   5.0621     0.9737   -0.4149
   5.0092     0.9686   -0.4158
   4.9526     0.9641   -0.4166
   4.8945     0.9606   -0.4172
   4.8377     0.9587   -0.4175
   4.7846     0.9591   -0.4174
   4.7377     0.9620   -0.4169
   4.6992     0.9675   -0.4160
   4.6713     0.9754   -0.4146
   4.6565     0.9852   -0.4128
   4.6545     0.9908   -0.4118
   4.6565     0.9965   -0.4109
   4.6713     1.0063   -0.4091
   4.6992     1.0142   -0.4077
   4.7377     1.0197   -0.4068
   4.7846     1.0226   -0.4063
   4.8377     1.0229   -0.4062
   4.8945     1.0211   -0.4065
   4.9526     1.0176   -0.4071
   5.0092     1.0130   -0.4079
   5.0621     1.0079   -0.4088
   5.1088     1.0029   -0.4097
   5.1475     0.9983   -0.4105
   5.1762     0.9947   -0.4112
   5.1937     0.9925   -0.4115
   5.1999     0.9908   -0.4118
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END

&PATCH1  IREV=  0,   IDPAT= 1,    MAKE=   24,   KCOMP= 1,    KASS= 1,        &END
         LOWER VERT TAIL TIP
&PATCH2  ITYP=  1,    TNODS= 3,    TNPS=   3,   TINTS= 3,    NPTTIP=0,       &END
```

```
&PATCH1  IREV= 0,    IDPAT= 2,    MAKE=   0,   KCOMP= 1,    KASS= 1,      &END
         HORIZ WING

&SECT1   STX=    4.6545, STY= 0.0000,    STZ= 0.0000,    SCALE=  .5454   ,
         ALF=  -2.0,  THETA=   0.0,
         INMODE=  5,  TNODS= 0,    TNPS=  0,    TINTS= 0,                 &END


&SECT2   RTC=    0.1200, RMC= 0.000,    RPC= 0.000,
         IPLANE=  2,  TNPC= 15,    TINTC= 0,                               &END
&SECT1   STX=    4.6545, STY= .8300,    STZ= 0.0000,    SCALE=  .5454   ,
         ALF=   -2.0,  THETA=   0.0,
         INMODE=  0,  TNODS= 5,    TNPS= 4,     TINTS= 2,                  &END


&WAKE1   IDWAK=1,         IFLXW=0,                                          &END
 WING WAKE INNER
&WAKE2   KWPACH=1,        KWSIDE=2,        KWLINE=0,        KWPAN1=0,
         KWPAN2=0,        NODEW=3,         INITIAL=1,                       &END
&SECT1   STX=  10.000, STY=    0.2545, STZ=     0.7000, SCALE=    1.0000,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 0,   TNODS= 3,    TNPS= 10,    TINTS= 1,                   &END

&WAKE1   IDWAK=1,         IFLXW=0,                                          &END
 WING WAKE OUTER
&WAKE2   KWPACH=3,        KWSIDE=2,        KWLINE=0,        KWPAN1=0,
         KWPAN2=0,        NODEW=5,         INITIAL=1,                       &END
&SECT1   STX=  10.000, STY=    0.9882, STZ=     0.7000, SCALE=    1.0000,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 0,   TNODS= 3,    TNPS= 10,    TINTS= 1,                   &END
```

```
&VS1     NVOLR= 0,        NVOLC= 0,                                          &END
&VS2     XO=     -2.0000, YO=      0.0000, ZO=     -2.0000,                  &END
&VS3     X1=      2.0000, Y1=      0.0000, Z1=     -2.0000, NPT1= 20,        &END
&VS4     X2=     -2.0000, Y2=      0.0000, Z2=     -2.0000, NPT2=  0,        &END
&VS5     X3=     -2.0000, Y3=      0.0000, Z3=      2.0000, NPT3= 40,        &END

&VS6     XRO=     0.0000, YRO=     0.0000, ZRO=     0.0000,                  &END
&VS7     XR1=     0.0000, YR1=    10.0000, ZR1=     0.0000,
         XR2=     0.0000, YR2=     0.0000, ZR2=     1.0000,                  &END
&VS8     R1=      0.5000, R2=      5.0000, PHI1=  0.0,      PHI2=330.0,      &END
&VS9     NRAD=  10,       NPHI=  12,       NLEN=  5,                         &END


&SLIN1   NSTLIN=0,                                                           &END
&SLIN2   SXO=    -3.0000, SYO=     0.0000, SZO=     0.0500,
         SU=      0.0000, SD=      6.5000, DS=      0.0250,                  &END
```

APPENDIX H
PMARC INPUT DATA FOR PIONEER LARGE TAIL SECTION

```
PIONEER LARGE TAIL

&BINP2   LSTINP=2,     LSTOUT=1,     LSTFRQ=0,     LENRUN=2,                       &END
&BINP3   LSTGEO=2,     LSTNAB=0,     LSTWAK=0,     LSTCPV=0,     LSTJET=0,         &END
&BINP4   MAXIT=75,     SOLRES=0.0005,                                              &END
&BINP5   NTSTPS=1,     DTSTEP=0.5,                                                 &END
&BINP6   RSYM=0.0,     RGPR=0.0,     RFF=5.0,      RCORE=0.05,                     &END
&BINP7   VINF=1.00,    VSOUND=1116.0,              UNIT=0,       COMPOP=0.0,       &END
&BINP8   ALDEG=-1.0,   YAWDEG=0.0,   THEDOT=0.0,   PSIDOT=0.0,   PHIDOT=0.0,       &END
&BINP9   CBAR=1.0,     SREF=9.10,    SSPAN=4.55,
         RMPX=0.33,    RMPY=0.00,    RMPZ=0.00,                                    &END
&BINP10  NORSET=0,     NBCHGE=0,     NCZONE=0,
         NCZPAN=0,     CZDUB=0.0,    VREF=0.0,                                     &END
&BINP11  NORPCH=0,     NORF=0,       NORL=0,
         NOCF=0,       NOCL=0,       VNORM=0.0,                                    &END
&BINP12  KPAN=0,       KSIDE=0,      NEWNAB=0,     NEWSID=0,                       &END

&ASEM1   ASEMX=0.00,       ASEMY=0.00,       ASEMZ=0.00,
         ASCAL=1.00,       ATHET=0.00,       NODEA=5,                              &END
&ASEM2   APXX=5.0363,        APYY=0.00,        APZZ=0.00,
         AHXX=5.0363,        AHYY=1.00,        AHZZ=0.00,                          &END

&COMP1   COMPX= 0.0000,    COMPY= 0.0000,    COMPZ= 0.0000,
         CSCAL=  1.000   , CTHET=    0.0,    NODEC= 5,                             &END
&COMP2   CPXX= 0.0000,     CPYY= 0.0000,     CPZZ= 0.0000,
         CHXX= 0.0000,     CHYY=  1.000   ,  CHZZ= 0.0000,                         &END


&PATCH1  IREV=  0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,              &END
          JUNCTION PATCH1

&SECT1   STX=     0.0, STY= 0.,     STZ= 0.000,    SCALE= 1.0    ,
         ALP=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 0,    TNPS=  1,     TINTS= 3,                         &END
   5.1996    1.5000    0.0190
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                         &END
   5.1935    1.5000    0.0171
   5.1760    1.5000    0.0143
   5.1474    1.5000    0.0096
   5.1090    1.5000    0.0036
   5.0624    1.5000   -0.0032
   5.0098    1.5000   -0.0101
   4.9533    1.5000   -0.0167
   4.8955    1.5000   -0.0223
   4.8388    1.5000   -0.0262
   4.7857    1.5000   -0.0277
   4.7387    1.5000   -0.0264
   4.7000    1.5000   -0.0221
   4.6719    1.5000   -0.0151
   4.6567    1.5000   -0.0057
   4.6545    1.5000    0.0000
   4.6563    1.5000    0.0058
   4.6708    1.5000    0.0163
   4.6984    1.5000    0.0253
```

```
   4.7366     1.5000     0.0322
   4.7834     1.5000     0.0367
   4.8365     1.5000     0.0390
   4.8933   · 1.5000     0.0391
   4.9514     1.5000     0.0375
   5.0082     1.5000     0.0349
   5.0612     1.5000     0.0316
   5.1081     1.5000     0.0281
   5.1469     1.5000     0.0248
   5.1758     1.5000     0.0222
   5.1933     1.5000     0.0205
   5.1996     1.5000     0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END

&SECT1   STX=     0.0, STY= 0.,     STZ= 0.000,     SCALE= 1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 3,    TNPS=  1,    TINTS= 3,                    &END
   5.1999     1.5885     0.0190
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                   &END
   5.1935     1.5862     0.0171
   5.1760     1.5845     0.0143
   5.1474     1.5819     0.0096
   5.1090     1.5777     0.0036
   5.0624     1.5738    -0.0032
   5.0098     1.5698    -0.0101
   4.9533     1.5655    -0.0167
   4.8955     1.5636    -0.0223
   4.8388     1.5625    -0.0262
   4.7857     1.5630    -0.0277
   4.7387     1.5658    -0.0264
   4.7000     1.5708    -0.0221
   4.6719     1.5777    -0.0151
   4.6567     1.5861    -0.0057
   4.6545     1.5909     0.0000
   4.6563     1.5840     0.0058
   4.6708     1.5721     0.0163
   4.6984     1.5623     0.0253
   4.7366     1.5554     0.0322
   4.7834     1.5517     0.0367
   4.8365     1.5510     0.0390
   4.8933     1.5528     0.0391
   4.9514     1.5563     0.0375
   5.0082     1.5619     0.0349
   5.0612     1.5677     0.0316
   5.1081     1.5735     0.0281
   5.1469     1.5785     0.0248
   5.1758     1.5829     0.0222
   5.1933     1.5856     0.0205
   5.1999     1.5885     0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END


&PATCH1  IREV= 0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,    &END
           JUNCTION PATCH2/UPPER TAIL


&SECT1   STX=     0.0, STY= 0.,     STZ= 0.000,     SCALE= 1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 0,                    &END
   5.1999     1.4741     0.6625
```

```
&BPNODE  TNODE = 0,  TNPC = 0,                                           &END
   5.1937     1.4724     0.6622
   5.1762     1.4702     0.6618
   5.1475     1.4666     0.6612
   5.1088     1.4620     0.6603
   5.0621     1.4570     0.6595
   5.0092     1.4519     0.6586
   4.9526     1.4473     0.6578
   4.8945     1.4438     0.6571
   4.8377     1.4420     0.6568
   4.7846     1.4424     0.6569
   4.7377     1.4452     0.6574
   4.6992     1.4507     0.6584
   4.6713     1.4586     0.6598
   4.6565     1.4684     0.6615
   4.6545     1.4741     0.6625
   4.6565     1.4797     0.6635
   4.6713     1.4895     0.6652
   4.6992     1.4974     0.6666
   4.7377     1.5029     0.6676
   4.7846     1.5058     0.6681
   4.8377     1.5062     0.6681
   4.8945     1.5043     0.6678
   4.9526     1.5008     0.6672
   5.0092     1.4963     0.6664
   5.0621     1.4912     0.6655
   5.1088     1.4862     0.6646
   5.1475     1.4816     0.6638
   5.1762     1.4780     0.6632
   5.1937     1.4758     0.6628
   5.1999     1.4741     0.6625
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                               &END

&SECT1   STX=    0.0, STY= 0.,    STZ= 0.000,    SCALE= 1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 3,    TNPS=  5,    TINTS= 3,                &END
   5.1999     1.5885     0.0190
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                               &END
   5.1933     1.5856     0.0205
   5.1758     1.5829     0.0222
   5.1469     1.5785     0.0248
   5.1081     1.5735     0.0281
   5.0612     1.5677     0.0316
   5.0082     1.5619     0.0349
   4.9514     1.5563     0.0375
   4.8933     1.5528     0.0391
   4.8365     1.5510     0.0390
   4.7834     1.5517     0.0367
   4.7366     1.5554     0.0322
   4.6984     1.5623     0.0253
   4.6708     1.5721     0.0163
   4.6563     1.5840     0.0058
   4.6545     1.5909     0.0000
   4.6565     1.5964     0.0013
   4.6713     1.6063     0.0025
   4.6992     1.6141     0.0038
   4.7377     1.6197     0.0051
   4.7846     1.6225     0.0063
   4.8377     1.6226     0.0076
   4.8945     1.6208     0.0089
```

```
    4.9526     1.6167     0.0101
    5.0092     1.6118     0.0114
    5.0621     1.6064     0.0127
    5.1088     1.6009     0.0139
    5.1475     1.5959     0.0152
    5.1762     1.5920     0.0165
    5.1937     1.5895     0.0177
    5.1999     1.5885     0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                      &END


&PATCH1  IREV= 0,   IDPAT= 1,    MAKE=   -2,  KCOMP= 1,    KASS= 1,             &END
         UPPER VERT TAIL TIP
&PATCH2  ITYP= 1,    TNODS= 3,    TNPS=   3,  TINTS= 3,    NPTTIP=0,            &END


&PATCH1  IREV= 0,    IDPAT= 1,    MAKE=   0,  KCOMP= 1,    KASS= 1,             &END
          JUNCTION PATCH3/LOWER TAIL

&SECT1   STX=    0.0, STY= 0.,     STZ= 0.000,    SCALE= 1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 4,   TNODS= 0,    TNPS=  1,     TINTS= 3,                      &END
   5.1999    1.5885     0.0190
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                      &END
    5.1935     1.5862     0.0171
    5.1760     1.5845     0.0143
    5.1474     1.5819     0.0096
    5.1090     1.5777     0.0036
    5.0624     1.5738    -0.0032
    5.0098     1.5698    -0.0101
    4.9533     1.5655    -0.0167
    4.8955     1.5636    -0.0223
    4.8388     1.5625    -0.0262
    4.7857     1.5630    -0.0277
    4.7387     1.5658    -0.0264
    4.7000     1.5708    -0.0221
    4.6719     1.5777    -0.0151
    4.6567     1.5861    -0.0057
    4.6545     1.5909     0.0000
    4.6565     1.5964     0.0013
    4.6713     1.6063     0.0025
    4.6992     1.6141     0.0038
    4.7377     1.6197     0.0051
    4.7846     1.6225     0.0063
    4.8377     1.6226     0.0076
    4.8945     1.6208     0.0089
    4.9526     1.6167     0.0101
    5.0092     1.6118     0.0114
    5.0621     1.6064     0.0127
    5.1088     1.6009     0.0139
    5.1475     1.5959     0.0152
    5.1762     1.5920     0.0165
    5.1937     1.5895     0.0177
    5.1999     1.5885     0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                      &END

&SECT1   STX=    0.0, STY= 0.,     STZ= 0.000,    SCALE= 1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE= 4,   TNODS= 3,    TNPS=  5,     TINTS= 0,                      &END
   5.1999    1.6635    -0.4118
```

```
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                        &END
   5.1937     1.6618    -0.4121
   5.1762     1.6596    -0.4125
   5.1475     1.6560    -0.4132
   5.1088     1.6514    -0.4140
   5.0621     1.6464    -0.4149
   5.0092     1.6413    -0.4158
   4.9526     1.6368    -0.4166
   4.8945     1.6333    -0.4172
   4.8377     1.6314    -0.4175
   4.7846     1.6318    -0.4174
   4.7377     1.6347    -0.4169
   4.6992     1.6402    -0.4160
   4.6713     1.6481    -0.4146
   4.6565     1.6579    -0.4128
   4.6545     1.6635    -0.4118
   4.6565     1.6692    -0.4109
   4.6713     1.6790    -0.4091
   4.6992     1.6869    -0.4077
   4.7377     1.6924    -0.4068
   4.7846     1.6953    -0.4063
   4.8377     1.6956    -0.4062
   4.8945     1.6938    -0.4065
   4.9526     1.6903    -0.4071
   5.0092     1.6857    -0.4079
   5.0621     1.6806    -0.4088
   5.1088     1.6756    -0.4097
   5.1475     1.6710    -0.4105
   5.1762     1.6674    -0.4112
   5.1937     1.6652    -0.4115
   5.1999     1.6635    -0.4118
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                        &END


&PATCH1  IREV=  0,    IDPAT= 1,    MAKE=   4,   KCOMP= 1,    KASS= 1,      &END
         LOWER VERT TAIL TIP
&PATCH2  ITYP=  1,    TNODS= 3,    TNPS=   3,   TINTS= 3,    NPTTIP=0,     &END


&PATCH1  IREV=  0,    IDPAT= 2,    MAKE=   0,   KCOMP= 1,    KASS= 1,      &END
         HORIZ WING1

&SECT1   STX=    4.6545, STY= 0.0000,    STZ= 0.0000,    SCALE=  .5454   ,
         ALF=  -2.0,  THETA=   0.0,
         INMODE=  5,  TNODS= 0,    TNPS=  0,    TINTS= 0,                  &END
&SECT2   RTC=    0.1200, RMC= 0.000,    RPC= 0.000,
         IPLANE=  2,  TNPC= 15,    TINTC= 0,                               &END
&SECT1   STX=    4.6545, STY= .8482,    STZ= 0.0000,    SCALE=  .5454   ,
         ALF=   -2.0,  THETA=   0.0,
         INMODE=  0,  TNODS= 3,    TNPS= 4,     TINTS= 2,                  &END

&PATCH1  IREV=  0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,      &END
         LOWER TAIL/BOOM PATCH

&SECT1   STX=    0.0, STY= .8482,    STZ= 0.000,    SCALE=  1.0   ,
         ALF=    0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 0,                  &END
    5.1996    0.0000    0.0190
 &BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                &END
    5.1935    0.0000    0.0171
```

```
   5.1760    0.0000    0.0143
   5.1474    0.0000    0.0096
   5.1090    0.0000    0.0036
   5.0624    0.0000   -0.0032
   5.0098    0.0000   -0.0101
   4.9533    0.0000   -0.0167
   4.8955    0.0000   -0.0223
   4.8388    0.0000   -0.0262
   4.7857    0.0000   -0.0277
   4.7387    0.0000   -0.0264
   4.7000    0.0000   -0.0221
   4.6719    0.0000   -0.0151
   4.6567    0.0000    0.0000
   4.6545    0.0000    0.0000
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END

&SECT1   STX=    0.0, STY= .8576,    STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  1,    TINTS= 0,                    &END
   5.1996    0.0000    0.0190
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                   &END
   5.1935    0.0000    0.0171
   5.1760    0.0000    0.0143
   5.1474    0.0000    0.0096
   5.1090    0.0000    0.0036
   5.0624    0.0000   -0.0032
   5.0098    0.0000   -0.0101
   4.9533    0.0000   -0.0167
   4.8955    0.0000   -0.0223
   4.8388    0.0000   -0.0262
   4.7857    0.0000   -0.0277
   4.7387    0.0000   -0.0300
   4.7000    0.0000   -0.0300
   4.6719    0.0000   -0.0300
   4.6567    0.0000   -0.0300
   4.6545    0.0000   -0.0300
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END

&SECT1   STX=    0.0, STY= .8832,    STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  1,    TINTS= 0,                    &END
   5.1996    0.0000    0.0190
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                   &END
   5.1935    0.0000    0.0171
   5.1760    0.0000    0.0143
   5.1474    0.0000    0.0096
   5.1090    0.0000    0.0036
   5.0624    0.0000   -0.0032
   5.0098    0.0000   -0.0101
   4.9533    0.0000   -0.0167
   4.8955    0.0000   -0.0223
   4.8388    0.0000   -0.0262
   4.7857    0.0000   -0.0277
   4.7387    0.0000   -0.0300
   4.7000    0.0000   -0.0325
   4.6719    0.0000   -0.0350
   4.6567    0.0000   -0.0400
   4.6545    0.0000   -0.0400
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END
```

```
&SECT1   STX=    0.0, STY= .9182,    STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  1,    TINTS= 0,                 &END
   5.1996    0.0000    0.0190
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                 &END
   5.1935    0.0000    0.0171
   5.1760    0.0000    0.0143
   5.1474    0.0000    0.0096
   5.1090    0.0000    0.0036
   5.0624    0.0000   -0.0032
   5.0098    0.0000   -0.0101
   4.9533    0.0000   -0.0167
   4.8955    0.0000   -0.0223
   4.8388    0.0000   -0.0262
   4.7857    0.0000   -0.0277
   4.7387    0.0000   -0.0300
   4.7000    0.0000   -0.0350
   4.6719    0.0000   -0.0400
   4.6567    0.0000   -0.0500
   4.6545    0.0000   -0.0500
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                 &END

&SECT1   STX=    0.0, STY= .9532,    STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  1,    TINTS= 0,                 &END
   5.1996    0.0000    0.0190
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                 &END
   5.1935    0.0000    0.0171
   5.1760    0.0000    0.0143
   5.1474    0.0000    0.0096
   5.1090    0.0000    0.0036
   5.0624    0.0000   -0.0032
   5.0098    0.0000   -0.0101
   4.9533    0.0000   -0.0167
   4.8955    0.0000   -0.0223
   4.8388    0.0000   -0.0262
   4.7857    0.0000   -0.0277
   4.7387    0.0000   -0.0300
   4.7000    0.0000   -0.0325
   4.6719    0.0000   -0.0350
   4.6567    0.0000   -0.0400
   4.6545    0.0000   -0.0400
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                 &END

&SECT1   STX=    0.0, STY= .9788,    STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  1,    TINTS= 0,                 &END
   5.1996    0.0000    0.0190
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                 &END
   5.1935    0.0000    0.0171
   5.1760    0.0000    0.0143
   5.1474    0.0000    0.0096
   5.1090    0.0000    0.0036
   5.0624    0.0000   -0.0032
   5.0098    0.0000   -0.0101
   4.9533    0.0000   -0.0167
   4.8955    0.0000   -0.0223
   4.8388    0.0000   -0.0262
   4.7857    0.0000   -0.0277
```

```
    4.7387    0.0000   -0.0300
    4.7000    0.0000   -0.0300
    4.6719    0.0000   -0.0300
    4.6567    0.0000   -0.0300
    4.6545    0.0000   -0.0300
 &BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END

 &SECT1   STX=     0.0, STY= .9882,    STZ= 0.000,    SCALE=  1.0    ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 3,    TNPS=  1,    TINTS= 0,                      &END
    5.1996    0.0000    0.0190
 &BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                   &END
    5.1935    0.0000    0.0171
    5.1760    0.0000    0.0143
    5.1474    0.0000    0.0096
    5.1090    0.0000    0.0036
    5.0624    0.0000   -0.0032
    5.0098    0.0000   -0.0101
    4.9533    0.0000   -0.0167
    4.8955    0.0000   -0.0223
    4.8388    0.0000   -0.0262
    4.7857    0.0000   -0.0277
    4.7387    0.0000   -0.0264
    4.7000    0.0000   -0.0221
    4.6719    0.0000   -0.0151
    4.6567    0.0000    0.0000
    4.6545    0.0000    0.0000
 &BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END


 &PATCH1  IREV=  0,    IDPAT= 1,    MAKE=   0,   KCOMP= 1,    KASS= 1,        &END
          UPPER TAIL/BOOM PATCH (FROM INNER TO OUTER EDGE)

 &SECT1   STX=     0.0, STY= .8482,    STZ= 0.000,    SCALE=  1.0    ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 0,                    &END
    4.6545    0.0000    0.0000
 &BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                   &END
    4.6563    0.0000    0.0000
    4.6708    0.0000    0.0163
    4.6984    0.0000    0.0253
    4.7366    0.0000    0.0322
    4.7834    0.0000    0.0367
    4.8365    0.0000    0.0390
    4.8933    0.0000    0.0391
    4.9514    0.0000    0.0375
    5.0082    0.0000    0.0349
    5.0612    0.0000    0.0316
    5.1081    0.0000    0.0281
    5.1469    0.0000    0.0248
    5.1758    0.0000    0.0222
    5.1933    0.0000    0.0205
    5.1996    0.0000    0.0190
 &BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                   &END

 &SECT1   STX=     0.0, STY= .8576,    STZ= 0.000,    SCALE=  1.0    ,
          ALF=   0.0,  THETA=   0.0,
          INMODE=  4,  TNODS= 2,    TNPS=  1,    TINTS= 0,                      &END
    4.6545    0.0000    0.0350
 &BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                   &END
```

```
   4.6563    0.0000    0.0350
   4.6708    0.0000    0.0350
   4.6984    0.0000    0.0350
   4.7366    0.0000    0.0350
   4.7834    0.0000    0.0367
   4.8365    0.0000    0.0390
   4.8933    0.0000    0.0391
   4.9514    0.0000    0.0375
   5.0082    0.0000    0.0349
   5.0612    0.0000    0.0316
   5.1081    0.0000    0.0281
   5.1469    0.0000    0.0248
   5.1758    0.0000    0.0222
   5.1933    0.0000    0.0205
   5.1996    0.0000    0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                          &END

&SECT1   STX=    0.0, STY= .8832,    STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  1,    TINTS= 0,           &END
   4.6545    0.0000    0.0500
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                          &END
   4.6563    0.0000    0.0500
   4.6708    0.0000    0.0400
   4.6984    0.0000    0.0400
   4.7366    0.0000    0.0400
   4.7834    0.0000    0.0400
   4.8365    0.0000    0.0400
   4.8933    0.0000    0.0391
   4.9514    0.0000    0.0375
   5.0082    0.0000    0.0349
   5.0612    0.0000    0.0316
   5.1081    0.0000    0.0281
   5.1469    0.0000    0.0248
   5.1758    0.0000    0.0222
   5.1933    0.0000    0.0205
   5.1996    0.0000    0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                          &END

&SECT1   STX=    0.0, STY= .9182,    STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  1,    TINTS= 0,           &END
   4.6545    0.0000    0.0600
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                          &END
   4.6563    0.0000    0.0600
   4.6708    0.0000    0.0550
   4.6984    0.0000    0.0525
   4.7366    0.0000    0.0500
   4.7834    0.0000    0.0450
   4.8365    0.0000    0.0400
   4.8933    0.0000    0.0391
   4.9514    0.0000    0.0375
   5.0082    0.0000    0.0349
   5.0612    0.0000    0.0316
   5.1081    0.0000    0.0281
   5.1469    0.0000    0.0248
   5.1758    0.0000    0.0222
   5.1933    0.0000    0.0205
   5.1996    0.0000    0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                          &END
```

```
&SECT1   STX=    0.0, STY= .9532,    STZ= 0.000,    SCALE=  1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  1,    TINTS= 0,                 &END
  4.6545    0.0000    0.0500
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                &END
  4.6563    0.0000    0.0500
  4.6708    0.0000    0.0400
  4.6984    0.0000    0.0400
  4.7366    0.0000    0.0400
  4.7834    0.0000    0.0400
  4.8365    0.0000    0.0400
  4.8933    0.0000    0.0391
  4.9514    0.0000    0.0375
  5.0082    0.0000    0.0349
  5.0612    0.0000    0.0316
  5.1081    0.0000    0.0281
  5.1469    0.0000    0.0248
  5.1758    0.0000    0.0222
  5.1933    0.0000    0.0205
  5.1996    0.0000    0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                &END

&SECT1   STX=    0.0, STY= .9788,    STZ= 0.000,    SCALE=  1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 2,    TNPS=  1,    TINTS= 0,                 &END
  4.6545    0.0000    0.0350
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                &END
  4.6563    0.0000    0.0350
  4.6708    0.0000    0.0350
  4.6984    0.0000    0.0350
  4.7366    0.0000    0.0350
  4.7834    0.0000    0.0367
  4.8365    0.0000    0.0390
  4.8933    0.0000    0.0391
  4.9514    0.0000    0.0375
  5.0082    0.0000    0.0349
  5.0612    0.0000    0.0316
  5.1081    0.0000    0.0281
  5.1469    0.0000    0.0248
  5.1758    0.0000    0.0222
  5.1933    0.0000    0.0205
  5.1996    0.0000    0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                &END

&SECT1   STX=    0.0, STY= .9882,    STZ= 0.000,    SCALE=  1.0    ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 3,    TNPS=  1,    TINTS= 0,               &END
  4.6545    0.0000    0.0000
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                &END
  4.6563    0.0000    0.0000
  4.6708    0.0000    0.0163
  4.6984    0.0000    0.0253
  4.7366    0.0000    0.0322
  4.7834    0.0000    0.0367
  4.8365    0.0000    0.0390
  4.8933    0.0000    0.0391
  4.9514    0.0000    0.0375
  5.0082    0.0000    0.0349
  5.0612    0.0000    0.0316
```

```
   5.1081    0.0000    0.0281
   5.1469    0.0000    0.0248
   5.1758    0.0000    0.0222
   5.1933    0.0000    0.0205
   5.1996    C.0000    0.0190
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                     &END


&PATCH1  IREV= 0,    IDPAT= 1,    MAKE=   0,  KCOMP= 1,    KASS= 1,            &END
         TAIL/BOOM JOINT

&SECT1   STX=    4.382, STY= 0.0,    STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 0,    TNPS=  1,    TINTS= 0,                      &END
   0.0     0.9882    0.0000
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                     &END
   0.0     0.9788    0.0350
   0.0     0.9532    0.0606
   0.0     0.9182    0.0700
   0.0     0.8832    0.0606
   0.0     0.8576    0.0350
   0.0     0.8482    0.0000
   0.0     0.8576   -0.0350
   0.0     0.8832   -0.0606
   0.0     0.9182   -0.0700
   0.0     0.9532   -0.0606
   0.0     0.9788   -0.0350
   0.0     0.9882    0.0000
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                     &END

&SECT1   STX=    4.6545, STY= 0.0,    STZ= 0.000,    SCALE=  1.0   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 3,    TNPS=  1,    TINTS= 0,                      &END
   0.0     0.9882    0.0000
&BPNODE  TNODE = 0,  TNPC = 0,  TINTC = 3,                                     &END
   0.0     0.9788    0.0350
   0.0     0.9532    0.0500
   0.0     0.9182    0.0600
   0.0     0.8832    0.0500
   0.0     0.8576    0.0350
   0.0     0.8482    0.0000
   0.0     0.8576   -0.0300
   0.0     0.8832   -0.0400
   0.0     0.9182   -0.0500
   0.0     0.9532   -0.0400
   0.0     0.9788   -0.0300
   0.0     0.9882    0.0000
&BPNODE  TNODE = 3,  TNPC = 0,  TINTC = 3,                                     &END


&PATCH1  IREV= 0,    IDPAT= 2,    MAKE=   0,  KCOMP= 1,    KASS= 1,            &END
         HORIZ WING1

&SECT1   STX=    4.6545, STY= 0.9882,   STZ= 0.0000,    SCALE=  .5454   ,
         ALF=  -2.0,  THETA=   0.0,
         INMODE=  5,  TNODS= 0,    TNPS=  0,    TINTS= 0,                      &END
&SECT2   RTC=    0.1200, RMC= 0.000,    RPC= 0.000,
         IPLANE=  2,  TNPC= 15,    TINTC= 0,                                   &END
&SECT1   STX=    4.6545, STY= 1.5,    STZ= 0.0000,    SCALE=  .5454   ,
         ALF=   -2.0,  THETA=   0.0,
```

```
         INMODE=  0,  TNODS= 3,    TNPS= 4,     TINTS= 2,                          &END

&PATCH1  IREV=  0,    IDPAT= 2,    MAKE=   0,  KCOMP= 1,    KASS= 1,               &END
          BOOM
&SECT1   STX=    4.3820, STY= .9182,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  7,  TNODS= 0,    TNPS=  0,    TINTS= 0,                          &END
         .070   0.0   0.0
&BPNODE          TNODE=  0,  TNPC=  0,  TINTC=0,                                   &END
         .070  30.0   0.0
         .070  60.0   0.0
         .070  90.0   0.0
         .070 120.0   0.0
         .070 150.0   0.0
         .070 180.0   0.0
         .070 210.0   0.0
         .070 240.0   0.0
         .070 270.0   0.0
         .070 300.0   0.0
         .070 330.0   0.0
         .070 0.0   0.0
&BPNODE           TNODE=  3,  TNPC=  0,  TINTC=3,                                  &END

&SECT1   STX=    4.350, STY= .9182,    STZ= 0.0000,    SCALE=  1.000   ,
         ALF=   0.0,  THETA=   0.0,
         INMODE=  4,  TNODS= 5,    TNPS=  0,    TINTS= 0,                          &END
         0.0   0.0   0.0
&BPNODE          TNODE=  3,  TNPC=  12,  TINTC=0,                                  &END


&WAKE1   IDWAK=1,         IFLXW=0,                                                 &END
 WING WAKE1
&WAKE2   KWPACH=6,        KWSIDE=2,        KWLINE=0,       KWPAN1=0,
         KWPAN2=0,        NODEW=3,         INITIAL=1,                              &END
&SECT1   STX=   5.000, STY=    0.0000, STZ=     0.0000, SCALE=    1.0000,
         ALF=   0.0,  THETA=   0.0,
         INMODE=-1,   TNODS= 3,    TNPS= 10,    TINTS= 1,                          &END

&WAKE1   IDWAK=1,         IFLXW=0,                                                 &END
 WING WAKE2

&WAKE2   KWPACH=10,        KWSIDE=2,        KWLINE=0,       KWPAN1=0,
         KWPAN2=0,        NODEW=5,         INITIAL=1,                              &END
&SECT1   STX=   5.000, STY=    0.0000, STZ=     0.0000, SCALE=    1.0000,
         ALF=   0.0,  THETA=   0.0,
         INMODE=-1,   TNODS= 3,    TNPS= 10,    TINTS= 1,                          &END

&VS1     NVOLR= 0,        NVOLC= 0,                                                &END
&VS2     X0=     -2.0000, Y0=     0.0000, Z0=    -2.0000,                          &END
&VS3     X1=      2.0000, Y1=     0.0000, Z1=    -2.0000, NPT1= 20,                &END
&VS4     X2=     -2.0000, Y2=     0.0000, Z2=    -2.0000, NPT2=  0,                &END
&VS5     X3=     -2.0000, Y3=     0.0000, Z3=     2.0000, NPT3= 40,                &END
&VS6     XR0=     0.0000, YR0=    0.0000, ZR0=    0.0000,                          &END
&VS7     XR1=     0.0000, YR1=   10.0000, ZR1=    0.0000,
         XR2=     0.0000, YR2=    0.0000, ZR2=    1.0000,                          &END
&VS8     R1=      0.5000, R2=     5.0000, PHI1=  0.0,     PHI2=330.0,              &END
&VS9     NRAD=  10,       NPHI=  12,      NLEN=  5,                                &END
&SLIN1   NSTLIN=0,                                                        .        &END
&SLIN2   SX0=   -3.0000, SY0=     0.0000, SZ0=    0.0500.

         SU=      0.0000, SD=     6.5000, DS=     0.0250,                          &END
```

APPENDIX I
PAD PLOTS (VARIOUS EXAMPLES)

The following figures show some of the plotting capabilities of the PAD program as well as some examples of how PMARC has been used to date as an analytical tool. Figures I.1 and I.2 show pressure coefficient plots along a wing in the chordwise and spanwise directions.

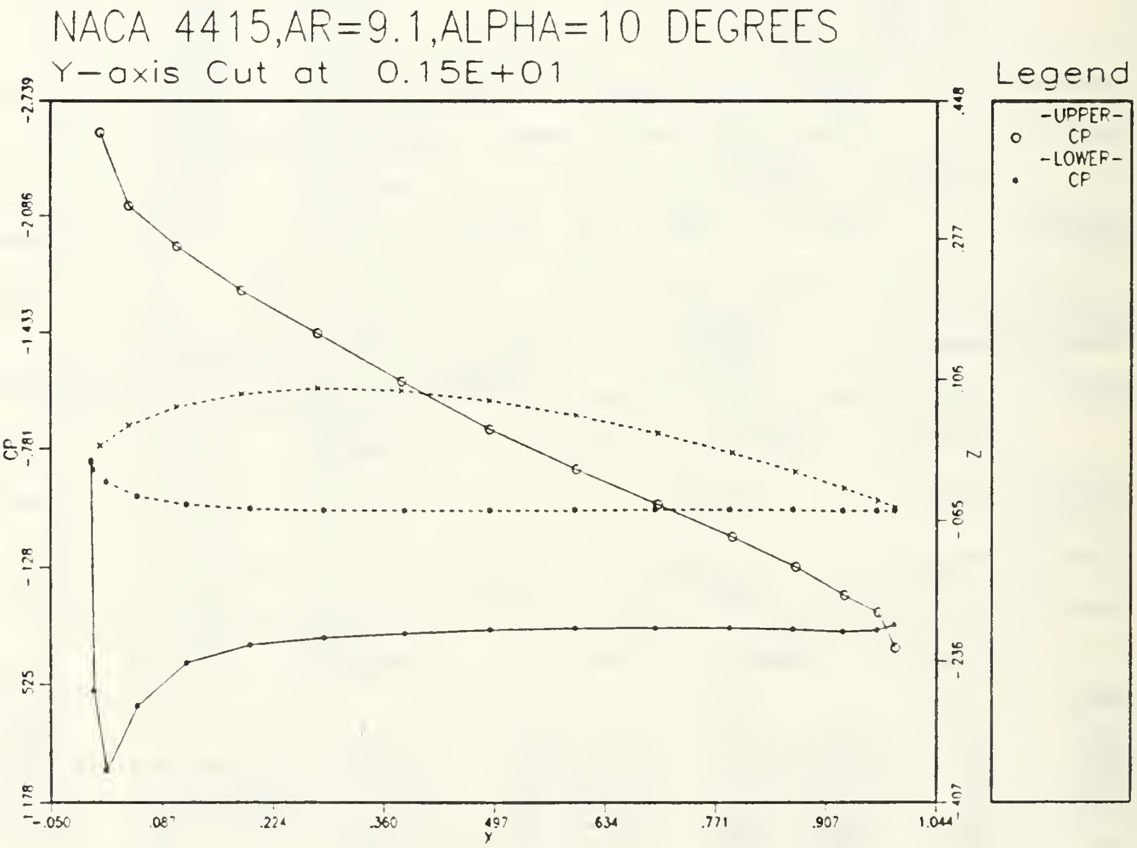


Figure I.1 Cp vs X (Chord Length)

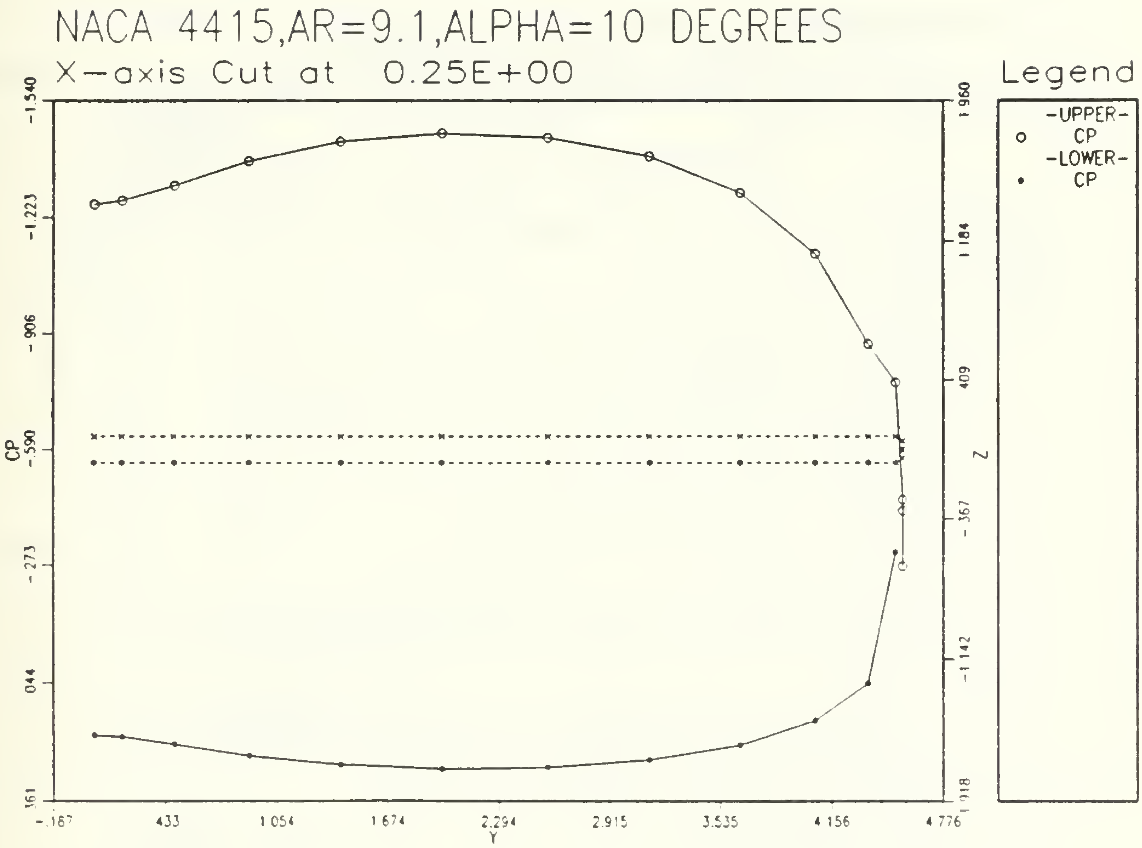


Figure I.2 Cp vs Y (Span Length)

Other plots from PAD include the overall surface velocity over the geometry (Figure I.3) and Cp and velocity superimposed on the same plot (Figure I.4).

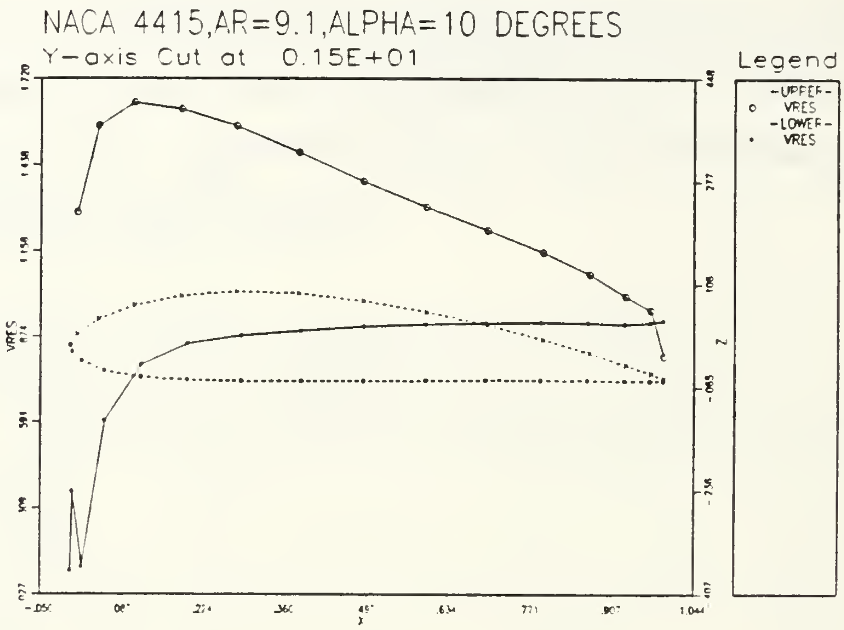


Figure I.3 Velocity vs X (Chord Length)

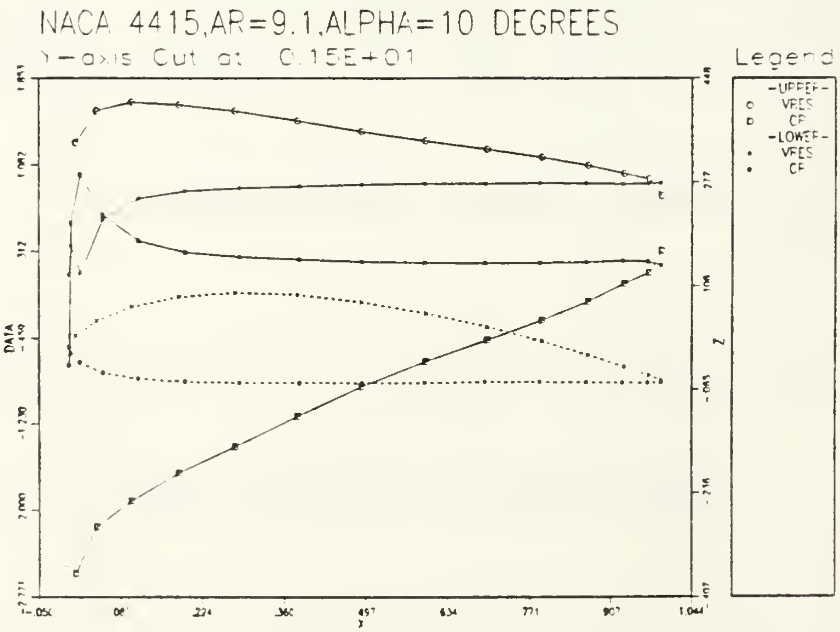


Figure I.4 Cp and Velocity vs X (Chord Length)

PAD also allows the plotting of dublet strength along a selected geometry. Note that in Figure I.5, the doublet strengths at the trailing edge are of approximately the same magnitudes for the upper and lower panels, but are of opposite signs. When the flow at the trailing edge is of equal direction and magnitude, the Kutta condition is met.

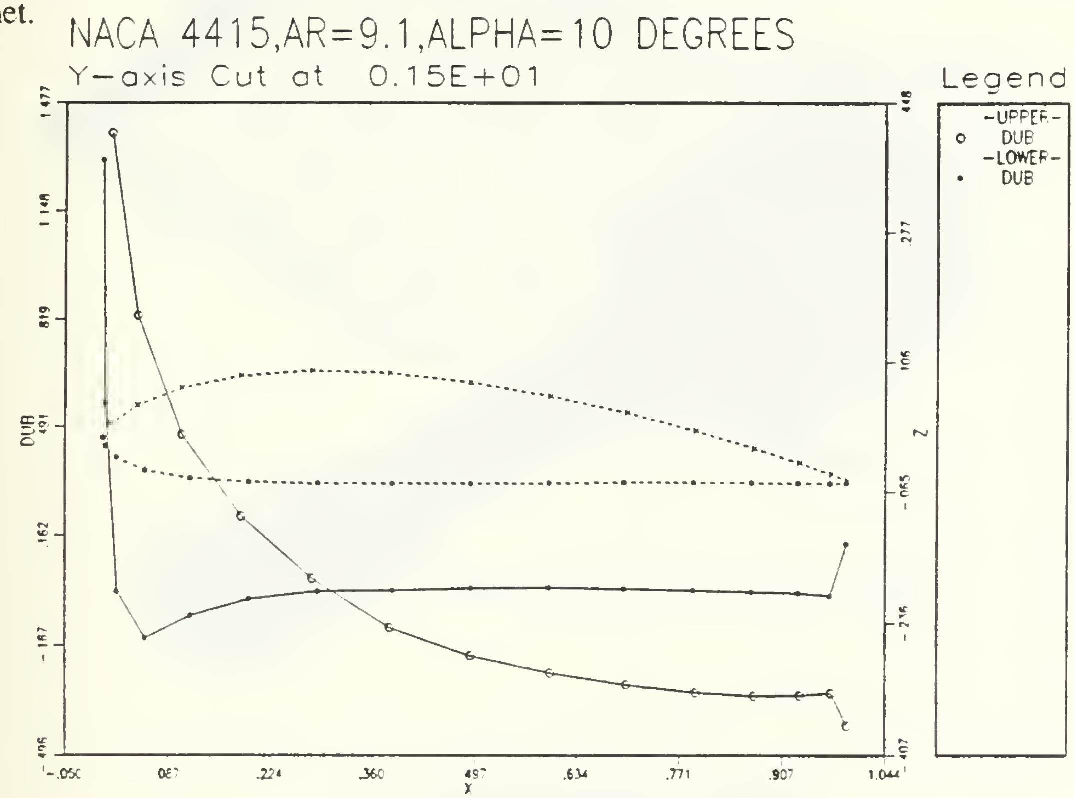


Figure I.5 Doublet Strength vs X (Chord Length)

The following examples show PAD plots from various PMARC test cases run at the NASA Ames Research Center. Figure I.6 shows a wing of aspect ratio 20 with its trailing wake. Note that the time stepping wake allows for the the tip vortex to roll up. Figure I.7 shows a rotating rotor blade. Work is currently underway to allow modelling of a moving rotor in conjunction with a fixed geometry such as a fuselage. Figure I.8 shows a model of the National Full Scale Aerodynamics

Complex 40x80 foot wind tunnel. PMARC has been used to calculate wind tunnel wall corrections by NASA engineers.

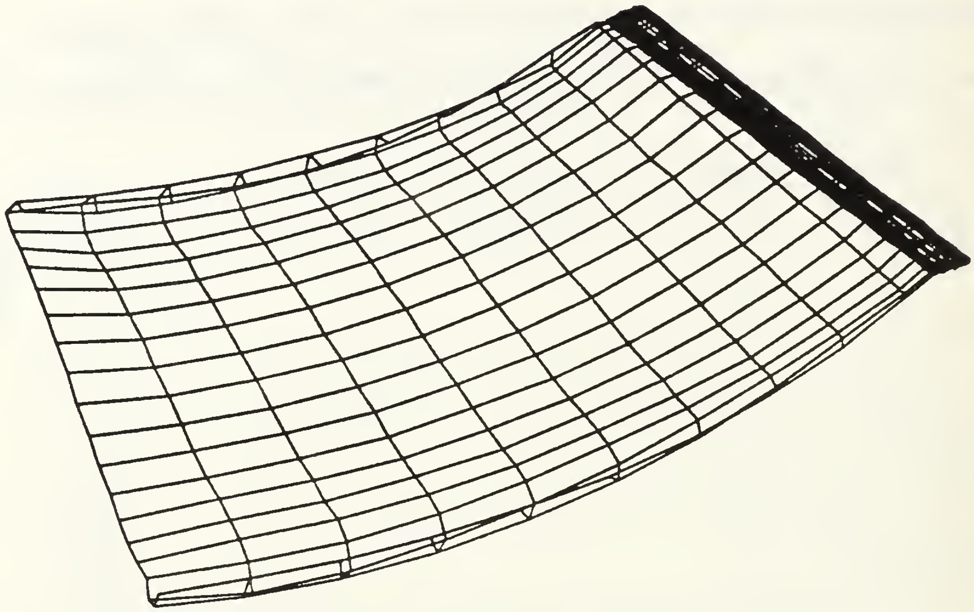


Figure I.6 PMARC Wing With Trailing Wake

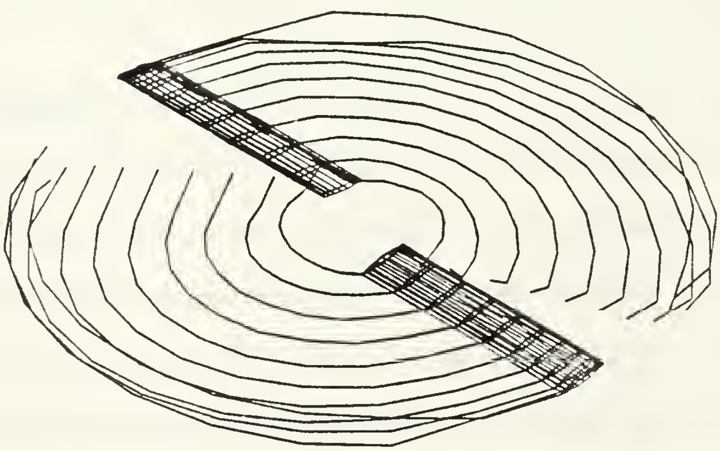


Figure I.7 PMARC Rotating Wing

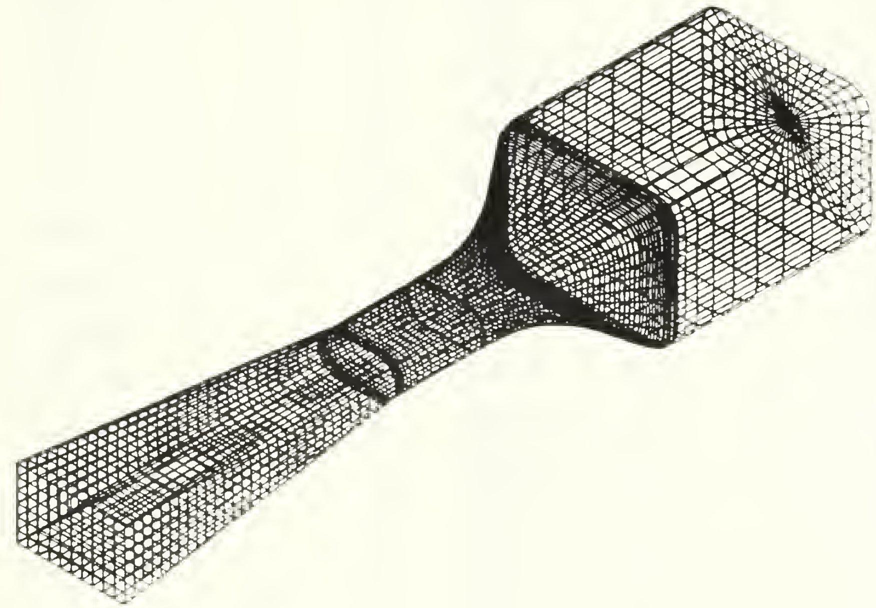


Figure I.8 PMARC Wind Tunnel Model

APPENDIX J
PMARC RESULTS

Appendix J contains the results from PMARC used in this study of PIONEER. The longitudinal runs were completed before the directional runs. Note that when the drag coefficient is zero, this means that the actual value was zero or in some cases a small negative value was obtained.

TABLE J.1 PIONEER (CG=33%MAC)

COMPONENT	PMARC Alpha (degrees)	CL	CD	Cm
Wing	-7	.0097	.0076	-.0891
Wing	-5	.1470	.0084	-.0734
Wing	-3	.2845	.0110	-.0575
Wing	-1	.4219	.0154	-.0414
Wing	1	.5588	.0215	-.0251
Wing	3	.6950	.0294	-.0088
Wing	5	.8299	.0390	.0074
Wing	7	.9633	.0502	.0235
Fuselage	-7	.0015	0.0	-.0684
Fuselage	-5	.0010	0.0	-.0565
Fuselage	-3	.0006	0.0	-.0442
Fuselage	-1	.0003	0.0	-.0317
Fuselage	1	.0002	0.0	-.0189
Fuselage	3	.0003	0.0	-.0059
Fuselage	5	.0005	0.0	.0073
Fuselage	7	.0009	0.0	.0205
Large Tail	-5	-.08	0.0	.3491
Large Tail	-1	-.0343	0.0	.1495
Large Tail	3	.0122	0.0	-.0527
Small Tail	-7	-.0623	0.0	.2736
Small Tail	-5	-.0486	0.0	.2133
Small Tail	-3	-.0346	0.0	.1520
Small Tail	-1	-.0204	0.0	.0900
Small Tail	1	-.0062	0.0	.0275
Small Tail	3	.0080	0.0	-.0350
Small Tail	5	.0223	0.0	-.0972
Small Tail	7	.0364	0.0	-.1591

TABLE J.2 PIONEER (CG=28%MAC)

COMPONENT	PMARC Alpha (degrees)	CL	CD	Cm
Wing	-5	.1470	.0084	-.0807
Wing	-1	.4219	.0154	-.0624
Wing	3	.6950	.0294	-.0436
Fuselage	-5	.0010	0.0	-.0565
Fuselage	-1	.0003	0.0	-.0317
Fuselage	3	.0003	0.0	-.0059
Large Tail	-5	-.0800	0.0	.3531
Large Tail	-1	-.0343	0.0	.1512
Large Tail	3	.0122	0.0	-.0533
Small Tail	-5	-.0486	0.0	.2158
Small Tail	-1	-.0204	0.0	.0910
Small Tail	3	.0080	0.0	-.0354

TABLE J.3 PIONEER (CG=38%MAC)

COMPONENT	PMARC Alpha (degrees)	CL	CD	Cm
Wing	-5	.1470	.0084	-.0662
Wing	-1	.4219	.0154	-.0203
Wing	3	.6950	.0294	.0259
Fuselage	-5	.0010	0.0	-.0564
Fuselage	-1	.0003	0.0	-.0317
Fuselage	3	.0003	0.0	-.0059
Large Tail	-5	-.0800	0.0	.3451
Large Tail	-1	-.0343	0.0	.1478
Large Tail	3	.0122	0.0	-.0521
Small Tail	-5	-.0486	0.0	.2109
Small Tail	-1	-.0204	0.0	.0889
Small Tail	3	.0080	0.0	-.0346

TABLE J.4 PIONEER (CG=33%MAC)

COMPONENT	PMARC Alpha (degrees)	CL	CD	Cm
Large Tail				
5° Elevator	-1	-.0717	.0016	.3189
5° Elevator	3	-.0251	0.0	.1156
10° Elevator	-1	-.1076	.0058	.4815
10° Elevator	3	-.0616	0.0	.2798
15° Elevator	-1	-.1427	.0116	.6404
15° Elevator	3	-.0977	.0042	.4417
20° Elevator	-1	-.1777	.7993	.7993
20° Elevator	3	-.1339	.0095	.6042
Small Tail				
5° Elevator	-1	-.0432	0.0	.1944
5° Elevator	3	-.0153	0.0	.0714
10° Elevator	-1	-.0662	.0023	.2994
10° Elevator	3	-.0383	0.0	.1757
15° Elevator	-1	-.0893	.0056	.4050
15° Elevator	3	-.0615	.0016	.2807
20° Elevator	-1	-.1130	.0099	.5134
20° Elevator	3	-.0854	.0048	.3888

TABLE J.5 PIONEER (large tail) (CG=33%MAC)

COMPONENT	PMARC Alpha (degrees)	CL	CD	Cm
PIONEER	-7	-.1329	.0161	.2742
PIONEER	-5	.0501	.0138	.2010
PIONEER	-3	.2290	.0184	.1306
PIONEER	-1	.4027	.0291	.0636
PIONEER	1	.5704	.0456	.0001
PIONEER	3	.7314	.0672	-.0594
PIONEER	5	.8849	.0932	-.1148
PIONEER	7	1.0304	.1228	-.1657

TABLE J.6 PIONEER (small tail) (CG=33%MAC)

COMPONENT	PMARC Alpha (degrees)	CL	CD	Cm
PIONEER	-7	-.0907	.0127	.0993
PIONEER	-5	.0833	.0113	.0629
PIONEER	-3	.2541	.0168	.0244
PIONEER	-1	.4207	.0288	-.0163
PIONEER	1	.5825	.0468	-.0588
PIONEER	3	.7385	.0703	-.1030
PIONEER	5	.8880	.0988	-.1487
PIONEER	7	1.0302	.1315	-.1955

TABLE J.7 PIONEER (CG=33%MAC)

COMPONENT/ Beta (degrees)	CL	CD	CY	Cm	Cn	Cl
Wing/5	.9207	.0388	.0022	-.0230	-.0029	.0128
Wing/10	.8997	.0375	.0043	-.0379	-.0056	.0249
Wing/15	.8656	.0353	.0062	-.0616	-.0081	.0357
Wing/20	.8192	.0325	.0077	-.0920	-.0102	.0447
Fuselage/5	-.0001	.0002	.0009	.0069	.0032	.0000
Fuselage/10	-.0019	.0007	.0026	.0059	.0060	.0000
Fuselage/15	-.0048	.0007	.0041	.0042	.0087	.0000
Fuselage/20	-.0088	.0011	.0055	.0021	.0111	.0000
Large Tail/5*	-.0141	.0000	-.0305	.0676	-.0299	-.0016
Large Tail/10*	-.0137	.0000	-.0586	.0694	-.0589	-.0029
Large Tail/15*	-.0132	.0000	-.0821	.0722	-.0861	-.0039
Large Tail/20*	-.0128	.0000	-.0990	.0757	-.1108	-.0043

*(elevator 5° up)

TABLE J.8 PIONEER (CG=33%MAC)

COMPONENT/ Rudder Deflection (degrees)	CL	CD	CY	Cm	Cn	Cl
Single Rudder						
Large Tail/5*	-.0126	.0024	-.0107	.0595	-.0108	-.0011
Large Tail/10*	-.0111	.0033	-.0214	.0525	-.0213	-.0021
Large Tail/15*	-.0098	.0048	-.0319	.0458	-.0314	-.0030
Large Tail/20*	-.0085	.0068	-.0422	.0394	-.0411	-.0040
Dual Rudders						
Large Tail/5*	-.0142	.0028	-.0214	.0671	-.0217	-.0021
Large Tail/10*	.0145	.0046	-.0428	.0681	-.0433	-.0043
Large Tail/15*	-.0150	.0076	-.0637	.0694	-.0645	-.0064
Large Tail/20*	-.0156	.0119	-.0842	.0711	-.0853	-.0084

*(elevator 5° up)

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